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Biological Control of the European Corn Borer in the United States

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Biological Control of the European Corn Borer[1] in the United States[2]

By W. A. BAKER, W. G. BRADLEY, and C. A. CLARK,[3] *entomologists, Division of Cereal and Forage Insect Investigations, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration*[4]

INTRODUCTION

THE EUROPEAN CORN BORER (*Pyrausta nubilalis* (Hbn.)), a pest of foreign origin, was first discovered in the United States in the summer of 1917. Losses of field and sweet corn due to this insect in large areas or in severely infested single fields in Canada and the United States establish this corn pest as one of the most destructive and threatening ones that have invaded this country. In view of the comparatively low per-acre value of the large fields of corn exposed to borer attack and the lack of inexpensive control methods, the possible utilization of biological means, including parasites, predators, and diseases, has been given considerable attention by the Department of Agriculture in its control program. The great increase in dispersion and abundance of the borer since 1942 has resulted in a demand by State and Federal workers for all available information on its natural enemies and their possible utilization. This bulletin presents information covering investigations conducted during the period 1919–40.

The early history of the program conducted by the Bureau of Entomology and Plant Quarantine for the introduction of foreign

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[1] *Pyrausta nubilalis* (Hbn.); order Lepidoptera; family Pyralidae; subfamily Pyraustinae.

[2] Submitted for publication March 10, 1949.

[3] Resigned August 1946.

[4] The following personnel contributed to the investigations reported herein: K. A. Bartlett, E. W. Beck, R. A. Biron, G. T. Bottger, E. D. Burgess, S. W. Carter, J. Coveney, C. A. Crooks, S. Dohanian, R. Ellis, R. T. Everly, D. W. Jones, L. G. Jones, R. Mathes, M. T. Myers, N. J. Nerney, A. M. Vance, and R. J. Webb. Assistance on the taxonomic phases of the work was given by C. F. W. Muesebeck. W. F. Sellers and D. G. Hall gave advice relative to the systematic position of certain species.

parasites of the European corn borer has been described by various writers. The more general phases of the work in Europe were presented by Thompson and Parker (*34, 35*).[5] Numerous papers treating specific species published by Thompson and Thompson (*36, 37*), H. L. Parker (*24, 25*), Parker and Smith (*26*), Vance (*39, 40, 41*), and Smith (*32*) were concerned principally with the general status of the various species in Europe, in conjunction with their morphology and laboratory biology. Cartwright's (*10*) discussion of the initial work in the Orient has been supplemented by Clark (*11*), following the completion of the Bureau's corn borer work in the Orient, thereby providing a comprehensive summary of that portion of the parasite program. Jones (*17, 18*) has presented brief accounts of the parasite investigations in the United States, and these reports have been supplemented by papers pertaining to certain phases of the domestic program, including laboratory and field studies of *Exeristes roborator* (F.) (Baker and Jones *2*), *Microgaster tibialis* Nees (Baker and Arbuthnot *1*), *Campoplex alkae* (Ell. and Sacht.) (Baker and Arbuthnot *1*), and the laboratory biology of *Zaleptopygus flavo-orbitalis* (Cam.) (Bradley and Burgess *8*). Since the appearance of these publications, the progress of the several parasites after their release in widely contrasting environments within the corn borer infested regions of the United States has been observed.

[5] Italic numbers in parentheses refer to Literature Cited, p. 183.

SYNONYMY

Certain corn borer parasites have been referred to in the literature under specific names other than those used in this bulletin. In order to obviate confusion in identity, the terminology used by the present writers and the names used for the same species in other publications, are shown in the following tabulation.

Terminology used in this bulletin	*Terminology used in previous references*
Diptera:	
Larvaevoridae:	
Aplomya caesar (Ald.)	*Zenillia caesar* Ald.
Aplomya mitis (Meig.)	*Exorista mitis* Meig. *Exorista nigripalpis* Towns. *Zenillia mitis* Meig.
Lydella stabulans var. *grisescens* R. D.	*Masicera senilis* Rond. *Masicera senilis* Auct. *Lydella grisescens* R. D. *Ceromasia lepida* (Meig.)
Pseudoperichaeta roseanae (B. & B.)	*Zenillia roseanae* (B. &. B.)
Hymenoptera:	
Braconidae:	
Apanteles thompsoni Lyle	*Apanteles* sp. (Europe)
Chelonus annulipes Wesm.	*Chelonus inanitus* Thomson *Chelonus* sp.
Macrocentrus gifuensis Ashm.	*Macrocentrus abdominalis* F.
Microbracon brevicornis Wesm.	*Habrobracon brevicornis* Wesm.
Eulophidae:	
Eulophus viridulus Thoms.	*Hemiptarsenus unguicellus* (Zett.)
Ichneumonidae:	
Campoplex multicinctus Grav.	*Campoplex rothii* Holmgr.
Campoplex pyraustae Smith	*Campoplex lugubrinus* Holmgr. *Campoplex* n. sp.
Zaleptopygus flavo-orbitalis (Cameron)	*Cremastus hymeniae* Viereck *Cremastus flavo-orbitalis* (Cameron)
Campoplex alkae (Ell. & Sacht.)	*Eulimneria crassifemur* Thomson *Eulimneria alkae* (Ell. & Sacht.)
Horogenes punctorius (Roman)	*Angitia punctoria* Roman *Dioctes punctoria* *Inareolata punctoria* (Roman)
Phaeogenes nigridens Wesm.	*Phaeogenes planifrons* Wesm.

IMPORTATIONS

Following the period 1919–27, covered by Jones (*18*), parasite material was imported from Europe almost every year through 1937. After the first trial shipments in 1927, parasite material from the Orient was obtained yearly through 1936.

Most of the parasites were received as immature larvae within the living host larvae. Nearly all importations were made during the winter while the parasites were in hibernation. The total numbers of corn borer larvae forwarded to the United States from Europe and the Orient from 1920 through 1938 to supply parasites for colonization are shown in table 1. Host larvae obtained from all foreign sources had reached a total of 26,867,608 by the end of 1939.

TABLE 1.—*Importations of European corn borer larvae to supply parasites for colonization in the United States, 1920–38*

Year	From Europe	From the Orient
	Number	*Number*
1920	[1] 20,207	
1921	[1] 76,258	
1922	[1] 76,645	
1923	0	
1924	[1] 8,105	
1925	[1] 154,408	
1926	[1] 502,600	
1927	[1] 1,500,000	60
1928	2,009,000	255
1929	1,272,600	147,269
1930	3,783,436	425,000
1931	4,461,975	681,400
1932	3,996,834	1,337,475
1933	3,494,972	120,000
1934	1,213,000	122,400
1935	1,141,393	134,592
1936	0	102,444
1937	85,280	
Total	23,796,713	3,070,895

[1] U. S. Dept. Agr. Tech. Bul. 98.

FROM EUROPE

The yearly importations of all species of European corn borer parasites from Europe are listed in table 2. In the early shipments of larval hosts from Europe, corn pith was used as a transportation medium, but later folded paper was substitued for the corn pith. Wooden boxes were used as containers. The method next adopted, and used also for larval shipments from the Orient, consisted in putting 300–400 larvae in a metal can. Most of the cans used were made of brass, copper, or tin alloy, and were about 5 inches deep and 3 inches in diameter, with metal-screen sides. To provide concealment for the larvae, each can contained a packet made of several strips of corrugated cardboard bound together, thus forming about 400 small tunnels in which the larvae could spin up. The cans were then placed in corrugated cardboard boxes and a number of these were packed for shipment in large wooden boxes.

In the shipments from Europe made during the years 1925–38, the host larvae were in packets consisting of 14 to 16 strips of single-faced corrugated cardboard, each strip being approximately ¾ inch wide and 4½ inches long, tied together with fine wire. A total of 150 packets was usually placed in a shipping box 24 by 11¼ by 5½ inches, inside measurements. The boxes were very tight and the covers were fastened on with screws. Some of them were lined with 30-mesh woven-wire cloth. No paper or other packing material was used. Each box contained an identification slip showing the number of host larvae, the

place and date of collection, and the name of the collector. In the years 1925–38 larval shipments were held in cold storage at approximately 40°–45° F. during the transoceanic trip.

Very few changes were made in the methods of shipping parasites imported after they had emerged from their hosts. No Diptera were imported other than as larvae within their hosts, except early in the study, when small numbers were brought in from Europe as puparia. Several species of Hymenoptera from both Europe and the Orient were imported in the cocoon stage. When handled in this stage the parasites were placed in pillboxes, which were packed tightly in wooden boxes. One lot of eulophid pupae from Europe was shipped in small glass vials plugged with cotton. The only other methods used to import corn borer parasites from Europe were adopted in the importation of the pupal parasite *Phaeogenes nigridens,* and have been described fully by Smith (*32*).

From the Orient

Host larvae in the later shipments from the Orient (Japan, Korea, and Manchuria) were in packets made up of 15 strips of double-faced corrugated cardboard, each strip being 1 inch wide by 4¾ inches long and capable of holding 27 or 28 larvae. Each packet was held together by two No. 14 rubber bands, was impregnated with beeswax, and was placed in an individual metal can 4¾ inches high and 2⅝ inches in diameter. Each can had two side openings, approximately 2 by 3 inches and covered with 30-mesh woven-wire cloth. In addition to the packet of corrugated cardboard, each can contained strips of newspaper, folded fanlike. Each can was placed in an individual corrugated-cardboard box. These were in turn packed in corrugated-cardboard cartons, 30 boxes to each carton, and crated for shipment.

Importations from the Orient did not reach the magnitude of those from Europe, because the Oriental species were introduced during a considerably shorter period and the total numbers imported were much smaller. The numbers of individuals of each parasite species imported yearly from the Orient are listed in table 3.

From Miscellaneous Sources

In 1936 and 1937, through cooperation with the Entomological Branch of the Canadian Department of Agriculture, 10,777 adults of the braconid *Chelonus annulipes* were imported for release in the United States. These importations consisted of individuals bred in the laboratory at Belleville, Ontario.

In August 1931, 5,000 puparia of *Paratheresia claripalpis* V. d. W., a tachinid fly parasitic on the sugarcane borer, were diverted from a shipment of over 70,000 being imported from Peru for release on the sugarcane borer in the Southern States. From this material 1,163 adults became available and were liberated in Saugus, Mass.

TABLE 2.—*Importations of European corn borer parasites from Europe*[1]

Species	1920–27	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	Total
Apanteles thompsoni Lyle	32,935	88,139	16,180	6,549	55,628	58,731	680						258,842
Bracon atricornis (Smith)				8		6	10						24
Campoplex multicinctus Grav.	[1]230	243	235	831		47	84						1,670
Campoplex pyraustae Smith	[1]325	903	218	276		41	36						1,799
Chelonus annulipes Wesm.			831	8,070	1,023	26,669	5,165	12,051			2,032		55,841
Campoplex alkae (Ell. & Sacht.)	57,865	18,204	9,601	13,336	22,512	20,988	1,631		4,470				148,607
Eulophus viridulus Thoms.				918	89,188	204,189	44,073	69,750					408,118
Exeristes roborator (F.)	1,411												1,411
Horogenes punctorius (Roman)	16,229	1,073	3,409	16,277	25,653	16,735	6,553	3,621	8,457		830		98,817
Lydella stabulans grisescens R. D.	10,940	27,619	8,378	190,388	129,316	132,095	74,405	37,906	135,050		5,539		751,636
Macrocentrus gifuensis Ashm.	5,965	59,567	21,984	20,996	9,004	3,563	132,712						253,791
Meteorus nigricollis Thoms.							8						8
Microbracon brevicornis (Wesm.)	1,300												1,300
Microgaster tibialis Nees	186,227	99,369	52,480	59,846	25,263	16,906	26,593		6	11,809			478,499
Phaeogenes nigridens Wesm.	24,058	1,273	2,008	4,523	4,560	21,018					5,081	10,806	73,327

Aplomya mitis (Meig.)	--------	285	83	2,796	258	59	202	--------	--------	--------	--------	--------	3,683
Pseudoperichaeta roseanae (B. & B.)	15,361	13,351	50,576	21,457	21,053	23,805	345	3,351	--------	--------	--------	--------	149,299
Labrorychus sp.	--------	--------	--------	--------	--------	--------	--------	--------	53	--------	--------	--------	53
Total	352,846	310,026	165,983	346,271	383,458	524,852	292,477	126,679	148,036	11,809	13,482	10,806	2,686,725

[1] The year of release is considered the year of importation. For the years 1920-27 importation records are taken from U. S. Dept. Agr. Tech. Bul. 98. For the year 1928-33 the number of parasites of each species liberated is considered the number imported. For the years 1934-38 the number of endo-parasites emerging in the United States is considered the number imported. For species shipped in the cocoon or pupal stage the number of individuals received is considered the number imported.

TABLE 3.—*Importations of European corn borer parasites from the Orient*[1]

Species	1929	1930	1931	1932	1933	1934	1935	1936	Total
Apanteles sp.	33		171	187					391
Bracon atricornis (Smith)	48	20	4	55	183	10	9	30	359
Zaleptopygus flavo-orbitalis (Cam.)	363	[2] 756	1,881	11,824	753	354	3,591	14,847	34,369
Campoplex alkae (Ell. & Sacht.)			564	7,937					8,501
Horogenes punctorius (Roman)		2,029	754	26,686			11		29,480
Lydella stabulans grisescens R. D.	13,452	15,697	24,309	14,717	544	8,038	13,431	9,897	100,085
Macrocentrus gifuensis Ashm.	([3])	3,906	41	124,645					128,592
Microgaster tibialis Nees			358	1,118					1,476
Nemorilla floralis (Fallen)				1,890					1,890
Phaeogenes nigridens Wesm.			38						38
Pseudoperichaeta erecta (Coq.)				1,616	6				1,622
Trichomma cnaphalocrosis Uchida				4					4
Xanthopimpla stemmator Thunb.				73					73
Total	13,896	22,408	28,120	190,752	1,486	8,402	17,042	24,774	306,880

[1]For the years 1929–33 the number of parasites of each species liberated or shipped to other laboratories is considered the number imported, excepted for *Trichomma cnaphalocrocis* and *Xanthopimpla stemmator*, the figures for which are the actual numbers imported. For the years 1934–36 the number of internal parasites emerging in the United States is considered the number imported. For species shipped in the cocoon stage, the number of individuals received is considered the number imported.

[2]30 cocoons and 13 adults imported, no releases.

[3]980 *Macrocentrus gifuensis* from Chosen and 414 from Japan imported in 1929, but not differentiated from European material in the release notes.

DOMESTIC COLLECTIONS

The first material from domestic sources, consisting of 11 adults of *Horogenes punctorius* and 163 of *Lydella stabulans grisescens,* was obtained through host-borer collections made in 1930 to determine the status of parasites around release points in New England. These collections indicated that considerable numbers of certain species of exotic parasites were present in the vicinity of the older release points in Massachusetts, and that material might be obtained from this section for distribution in other parts of the infested area.

In the summer of 1931 the first material was collected to determine the feasibility of obtaining parasites from established colonies for release in noncolonized districts. After the ears had been harvested, the entire stalks from about 0.37 acre of sweet corn carrying the highest parasite concentration in the vicinity of Malden, Mass., were cut and stored in an improvised emergence loft. In the following two years the first-generation borers were obtained by cutting and storing only that part of the plant above the ear. Thus the borers could be placed in storage before any appreciable numbers of parasites had emerged in the field, and releases could be better synchronized with the presence of the host borers. In 1932 and 1933 second-generation borers were obtained by storing entire stalks of infested corn in the fall to supply parasites for colonization in 1933 and 1934.

Although it seemed probable that parasites could be supplied economically by the above method, one outstanding limitation was apparent. To synchronize the emergence of parasites with the occurrence of host borers in a suitable stage for parasitization, storage and emergence rooms in which temperature and moisture could be controlled, were needed. In the fall of 1935 the first attempt was made to remove the borers from their host plants and store them under conditions of controlled temperature and humidity.

Records of the collections of corn borer larvae for obtaining parasites from domestic sources are summarized in table 4.

A survey in the vicinity of the first liberation points north and west of Boston showed that parasitization of first-generation borers in 1929, 1931, and 1932 averaged 28.8, 28.9, and 24.0 percent, respectively. During the same years parasitization of the second-generation borers averaged 6.9, 9.9, and 15.2 percent, respectively. However, maximum parasitization in individual fields infested by second-generation borers was as high as that of first-generation borers in the same season. Considerable variation was noted also in the parasitization of borers of like generations in different years.

Prior to the actual collection of host larvae, surveys were made to determine desirable fields from which borers should be taken. In earlier years the basis of choice was the number of exotic parasites in 100 stalks, the fields carrying the greatest concentration being utilized first. After 1934, when selecting fields, the parasite species most desired for distribution was given first consideration. Table 5 presents data obtained in such precollection surveys.

To obtain borers for storage under controlled temperature and humidity conditions, the standing corn in the fields to be utilized was purchased, and the collection of parasite material was started usually about November 1. This date was selected because (1) the parasite-host relationship had reached equilibrium for the season; (2) borer activity was reduced to a low point, so that host-plant material could be handled with a minimum of migration; and (3) seasonal observations on the field status of parasites could be completed before domestic collections were started.

Two men were employed in cutting the corn, a third in tying the stalks into bundles, and a fourth, with help, loaded, unloaded, and trucked the corn to the dissection place. From 20 to 30 men were employed in dissecting the corn and removing the corn borer larvae from the stalks. Since the field group could cut, tie, and truck the corn almost twice as fast as 25 men could dissect it, the field men became available at times to aid in removing the larvae from the corn.

TABLE 4.—*Collections of European corn borer larvae for obtaining parasites from domestic sources*

Generation of host larvae	Year of release of parasites	Host larvae utilized	Method of storage
		Number	
First	1931	([1])	In host plants.
Do	1932	327,924	Do.
Second	1933	543,432	Do.
First	1933	190,150	Do.
Second	1934	1,062,566	Do.
Do	1936	166,988	In corrugated-paper cores.
Do	1937	191,265	Do.
Do	1939	3,000	Do.
Do	1940	20,068	Isolated in individual glass vials.

[1]All the borers that were present in about 0.37 acre of corn. (About 40,000 borers.)

A greenhouse 50 by 100 feet was utilized for the dissection work. The 20 to 30 cutters seated on boxes in a long row on one side of the greenhouse, with cornstalks piled in front of them, were able to remove approximately 500 larvae per day per man. Corn debris was tossed in a pile behind the cutters, whence it could be removed easily and burned. So far as possible, the available corn was dissected in the order of its estimated value as a source of parasite material, that containing the largest number of the most important parasite being used first.

The larvae were placed in light metal cans about 3 inches in diameter and 5 inches high, with a funnel soldered in the cover, and containing newspaper folded fanlike to prevent the larvae from injuring each other. These collecting cans were taken at intervals to a table, where the larvae were sorted. All dead or injured borers were removed and the healthy ones were counted

TABLE 5.—*Infestation of host plants and parasitization of European corn borers, as estimated from precollection surveys for domestic collection, eastern Massachusetts, 1931–36*

Year of examination	Generation of borers	Fields examined	Total area	Estimated larvae		Borers parasitized	Estimated parasites in field
				Per 100 plants	In fields		
		Number	*Acres*	*Number*	*Number*	*Percent*	*Number*
1931	First	2	0.37				[1]2,310
1932	do	19	18.95	60.6	327,924	12.76	41,843
1932	Second	12	7.55	30.7	543,432	22.14	120,316
1933	First	13	10.55	80.0	190,150	14.21	27,020
1933	Second	12	6.58	603.1	1,062,566	7.55	80,224
1935	do	24	19.1	510.8	1,175,682	17.30	203,392
1936	do	12	17.8	218.6	507,225	22.23	112,756

[1]Number actually recovered.

and allowed to spin up in packets made of strips of corrugated cardboard. Four hundred larvae were placed in each packet. The packets were boxed and shipped by express to the Moorestown, N. J., laboratory, where they were placed in cold storage.

The number of healthy larvae actually obtained from the various fields was much less than the number of larvae estimated to be in the corn at the time of the precollection survey. The total loss from all causes amounted to 78.1 percent, most of which was probably due to normal reduction in the field caused by mortality and migration of the larvae, and by birds and other predators. However, additional losses occurred through injury during harvest and dissection operations, and through migration of larvae during the transportation and handling of the cornstalks. Data on mortalities incident to shipment were obtained by sample counts made of the Massachusetts larvae when they were placed in cold storage at the Moorestown, N. J., laboratory. Most of the dead larvae found were outside the packets when the shipments were received. Many of them were either very small, immature individuals or mature larvae that had been injured in collection. In the fall of 1935 the mortality of larvae during shipment averaged 2.5 percent; in 1936, 3.3 percent.

TABLE 6.—*Numbers of European corn borer parasites obtained from domestic collections of borers*

Year	*Horogenes punctorius*	*Lydella stabulans grisescens*	*Phaeogenes nigridens*	*Pseudoperichaeta roseanae*	*Macrocentrus gifuensis*	Total
1930	11	163				174
1931	2,225	1,144				3,369
1932	7,909	1,637	156	2,240		11,942
1933	8,068	1,272	66	233		9,639
1934	5,000	1,411				6,411
1936	14,871	6,175				21,046
1937	10,149	2,239				12,388
1939					2,177	2,177
1940					78,815	78,815
Total	48,233	14,041	222	2,473	80,992	145,961

Data on the number of parasites obtained for release in the United States from domestic collections of borers in the vicinity of the older release points in eastern Massachusetts are presented in table 6.

In addition to domestic collection of borers to obtain parasites for colonization, small numbers of *Horogenes punctorius* and *Macrocentrus gifuensis* adults were reared from borers collected in 1939 and 1940 to determine the current status of parasites.

LABORATORY BREEDING

The principal source of parasites for colonization in the United States was in the laboratory; however, only five species were obtained by this means, and 90 percent of the total number of adults were *Microbracon brevicornis*. The breeding work with

M. brevicornis and *Exeristes roborator* in the Eastern States was completed in 1926 and was started at Monroe, Mich., in the spring of 1927. All the adults reared at Monroe were released in the Lake States area in 1931. Details of the technique employed in rearing these two parasites are given by Jones (*18*) and Baker and Jones (*2*).

Chelonus annulipes, the egg-larval parasite from Europe, was the third parasite to be bred successfully in the laboratory. Starting in 1929, adults were produced each year through 1933, utiliz-

TABLE 7.—*Numbers of European corn borer parasites obtained by breeding in laboratories in the United States*

Year	*Apanteles thompsoni*	*Chelonus annulipes*	*Exeristes roborator*	*Microbracon brevicornis*	*Microgaster tibialis*	Total
1922				1,054,000		1,054,000
1923			28,935	2,714		31,649
1924			19,954	50,550	1,200	71,704
1925			22,433	156,370		178,803
1926			48,407	65,584		113,991
1927			53,635	239,063		292,698
1928	5		59,896	582,287	2,308	644,496
1929		221	46,441	354,087		400,749
1930		2,016	34,342	279,824		316,182
1931		4,272	959	9,691		14,922
1932		741				741
1933		1,342				1,342
1938		133,424		29,073		162,497
1939		75,818				75,818
Total	5	217,834	315,002	2,823,243	3,508	3,359,592

TABLE 8.—*Numbers of European corn borer parasites obtained from all sources of biological control investigations, 1920–39*

Year	Importations from—			Domestic collections	Laboratory breeding	Total
	Europe	The Orient	Canada and Peru			
1920–27	352,846	([1])			1,742,845	2,095,691
1928	310,026	([2])			644,496	954,522
1929	165,983	13,896			400,749	580,628
1930	346,271	22,408		174	316,182	685,035
1931	383,458	28,120	5,000	3,369	14,922	434,869
1932	524,852	190,752		11,942	741	728,287
1933	292,477	1,486		9,639	1,342	304,944
1934	126,679	8,402		6,411		141,492
1935	148,036	17,042				165,078
1936	11,809	24,774	10,777	21,046		68,406
1937	13,482			12,388		25,870
1938	10,806				162,497	173,303
1939				2,177	75,818	77,995
Total	2,686,725	306,880	15,777	67,146	3,359,592	6,436,120

[1] A few larvaevorid parasites emerged from material imported during 1927.
[2] 15 larvaevorids and 19 hymenopterons emerged from material imported in 1928.

ing the European corn borer as the host. In 1938 and 1939 large numbers of *C. annulipes* were bred on *Ephestia kuehniella* Zell.

The braconid *Microgaster tibialis* was bred in the years 1924 and 1928 in numbers sufficient to permit releases.

A few individuals of *Apanteles thompsoni* were bred for release in 1928. Table 7 summarizes the production of parasites by laboratory breeding, and table 8 summarizes by years the parasites obtained from all sources for release in the United States. Methods of obtaining eggs and rearing corn borer larvae for use in breeding corn borer parasites are given by Patch and Pierce (*28*) and Baker and Mathes (*3*).

STORAGE OF PARASITE MATERIAL

Shipments of host larvae from foreign countries were made while the borers were in hibernation. The material arrived between October and May, the greater part of it being received during the winter. Late shipments in the spring were attended by increased activity among the borers and, consequently, by greater mortality.

In the first consignments, host larvae containing endoparasites were shipped in corn, which was stored in outdoor insectaries without removing the larvae from their tunnels. No manipulation of the atmospheric environment or extension of the dormant period was attempted and the material was subjected to the prevailing outdoor weather conditions as they affected the material in the insectaries. Later material with the larvae webbed up in corrugated-cardboard packets was stored in an underground chamber having stone walls and an earthen floor, and where some slight environmental control was exerted. The earthen floor and the walls were sprayed periodically with water to induce a higher humidity.

In the spring large quantities of ice were placed in a rack at one side of the chamber, and the packets containing the host larvae were removed from the shipping boxes and arranged one layer deep in shallow racks having bottoms of 1-inch-mesh wire. These racks were stacked one above the other until they formed a solid column about 6 feet high. When they were all in place the entire column was wrapped in cheesecloth and cemented over with a one-half inch layer of plaster of paris. In earlier years water was sprayed onto this column at intervals during the storage period in order to increase the humidity within the stack, but in later tests no moisture was added to the column. However, by this method of storage, a gradual rise in temperature was unavoidable, and this was attended by a slow increase in metabolic activity of the larvae.

This undesirable condition was remedied during the first winter (1934–35) that the host larvae were stored at the laboratory at Moorestown. A walk-in refrigerator with controlled temperature and humidity was used. When the shipping boxes arrived at Moorestown, after being carried by automobile from the steamer at New York, a sample of the contents was taken to estimate the mortality incurred since they were packed. The mortality during shipment was estimated by examining 20 larvae in each of 10

packets taken at random from each box, and by counting the dead larvae in each box outside the packets. The mortality of the host larvae imported from both Europe and the Orient was very low during transportation, never rising above 3.5 percent.

On receipt of the larvae at Moorestown, qualitative and quantitative observations on the parasitization in the host larvae were also made. The data were derived by dissecting 10 larvae from each of five packets taken at random from each box of material.

Following the examination as outlined above, all parasite material was repacked in the boxes in which it was received, and was left in these containers throughout the storage period. The temperature and the relative humidity of the storage room (fig. 1) during this time was 35° F. and approximately 90 percent, respectively, maintained by electrically controlled apparatus until development was started.

All parasite material received in the cocoon stage was handled during the storage period by the method described by Arbuthnot and Baker.[6] When held under conditions provided at the Moorestown, N. J., laboratory, the mortality of the corn borer larvae during storage was low, the average mortality in imported material not exceeding 5.3 percent. In domestic collections mortalities as high as 13.8 percent were noted, possibly owing to the inclusion of immature borers. Increasing the length of winter storage beyond the normal hibernation period invariably resulted in some increase in mortality.

EMERGENCE

Synchronizing releases

Prior to the use of equipment permitting control of the environment during the storage period, it was impossible to control accurately the time of emergence of endoparasites. Some retardation was effected by the methods previously described, but the time of removal of material from the storage chambers was determined by the seasonal activity of the larvae and not by the dates of a predetermined release program. The time of resumption of activity of the host borers varied from year to year with their source and also with climatic conditions.

During these early years the entire accumulation of host larvae was removed on one date when observations showed that further storage would result in excessive mortality caused by activity of the confined larvae. On this date the plaster-of-paris columns were broken open and the trays containing the borers that had spun up in the corrugated-cardboard packets, were transferred to outdoor insectaries, where they were stacked in staggered columns, each rack separated from the one below by small blocks of wood placed at the corners to permit egress of the emerging adults. The technique of handling from this point was the same,

[6] Arbuthnot, K. D., and Baker, W. A. Technique and equipment for handling two hymenopterous parasites of the European corn borer with particular reference to prolonging their hibernation. U. S. Bur. Ent. and Plant Quar., E–460, 12 pp., illus. 1938. [Processed.]

both before and after more efficient storage methods were developed. The original storage procedure was inadequate to supply parasites for liberation, because the emergence of the imported parasites could not be controlled so that releases would synchro-

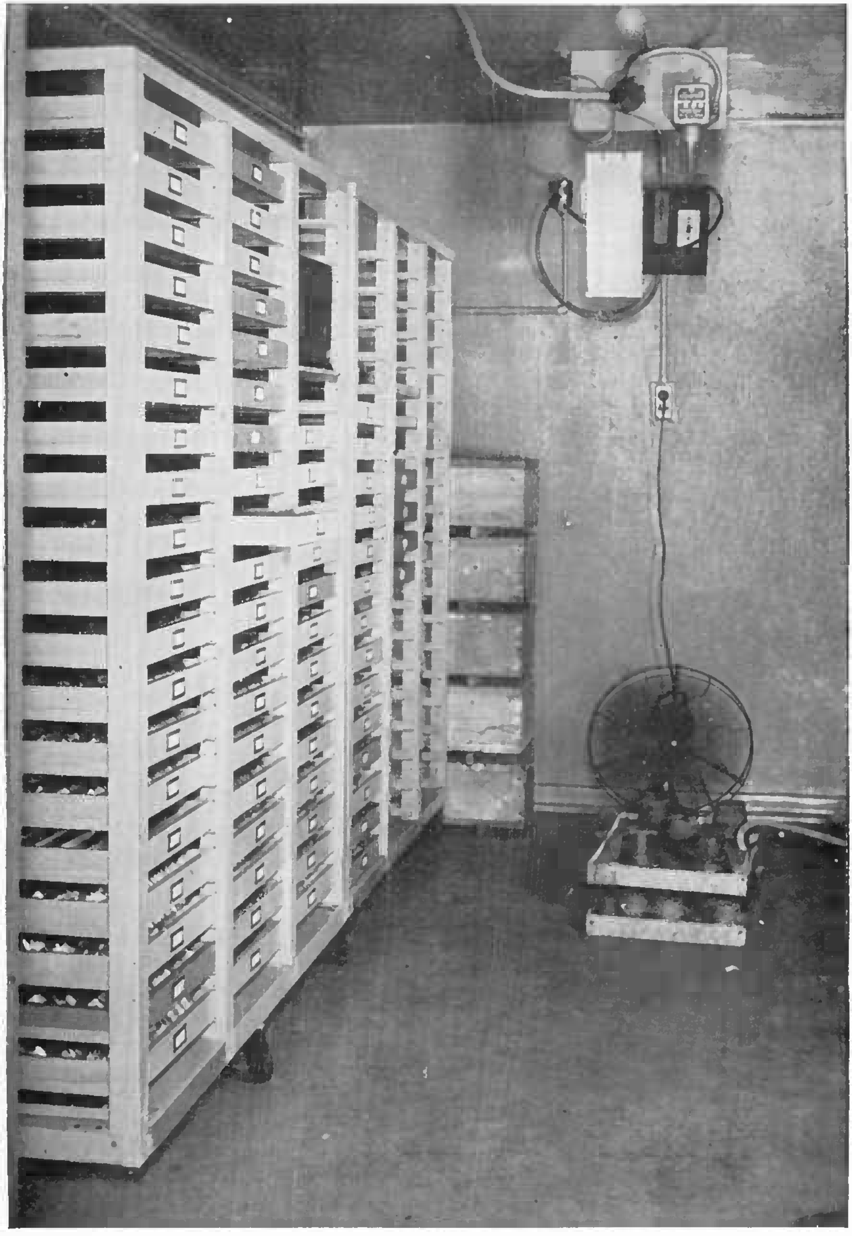

FIGURE 1.—Storage room for parasite material, European corn borer laboratory, Moorestown, N. J.

nize with the occurrence of the host in a preferred stage of development.

Synchronization of parasite releases with the presence of suitable hosts was complicated by several factors. Part of the endoparasitic material was collected from areas in which one annual generation of the borer prevailed, and part of it was obtained in areas having two or more annual generations. When stored and developed in a common environment, this host material developed at different rates, depending on its source. Furthermore, it was often desirable to release parasites obtained from any given shipment at more than one point in the infested area. The different geographic positions of the release points necessitated different release dates, depending on the strain of the host and on the meteorological conditions prevailing in the respective localities. Because of the variation in these factors, it was often necessary to move successive lots of the host material containing parasites destined for various points in the infested area into a developmental environment in order to obtain emergence at the proper times for release in the different localities.

Since obviously it is impossible to vary to any great extent the normal date of emergence of one species of endoparasite more than that of another in the same lot of material after it has been placed in a developmental environment, it was necessary with each lot to choose a prospective emergence date that would be optimum for the most important of the species expected from it. Fortunately, variations in such factors as release localities, oviposition requirements for preferred host stages, the developmental period within the host, and the duration of the preoviposition period, permitted a fairly close synchronization of all parasites.

That close attention to synchronization resulted in higher initial establishment has been demonstrated. Baker and Arbuthnot (*1*) have pointed out its value with respect to the colonization of *Microgaster tibialis*. Immediately after liberation, however, the seasonal rhythm of this parasite reverts to that of the region of its origin. Nevertheless, in general, a high initial establishment resulting from synchronization of parasite releases with the proper growth stages of the host is believed to increase the chances for a colony's success over that of a nonsynchronized release, even with parasites having habits similar to *M. tibialis*.

While the ultimate worth of synchronized releases of parasites that revert immediately to a seasonal rhythm nonsynchronous with the host cycle may not be demonstrable, yet with parasites the development of which depends chiefly on host physiology, synchronization is of definite value. This was clearly shown in the *Chelonus annulipes* released in the Lake States. This parasite oviposits in corn borer eggs and the parasite larva issues when the host is in the fourth instar. The week preceding the peak of host oviposition in the respective localities was chosen for the release of *C. annulipes* adults, since they are capable of ovipositing very soon after emergence, and since from 200 to 300 eggs may be deposited over a considerable period by one female. It was thought that liberations just prior to the peak of host oviposition would insure a maximum number of host eggs for

parasitization immediately after the releases, and would provide for the greatest possible utilization of the oviposition capacity of the parasite. By applying this plan to a series of *C. annulipes* releases, it became evident that synchronization played an important part in initial establishment of the parasite.

Figure 2 shows the extent of synchronization of releases of *Chelonus annulipes* at two points in the Lake States. Figure 2, *A*, shows that complete or partial synchronization was accomplished with most of the adult parasites released in Jerusalem Township, Lucas County, Ohio. Establishment and maintenance over a number of years were obtained at this location. In the

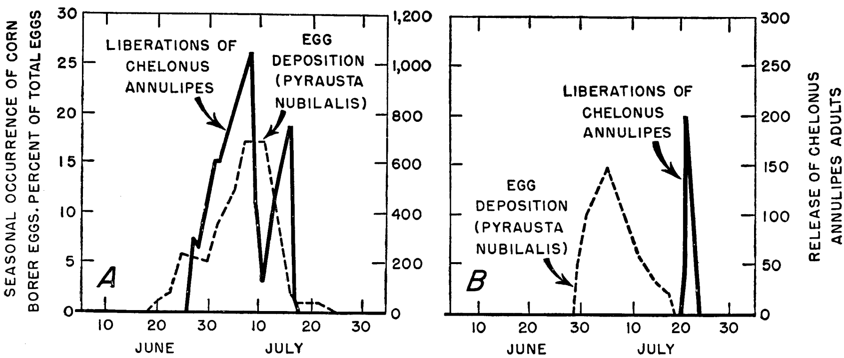

FIGURE 2.—Synchronization of *Chelonus annulipes* releases with the presence of host eggs, 1930; *A*, Jerusalem Township, Lucas County, Ohio; *B*, Monroe, Mich.

locality represented by figure 2, *B*, there was no synchronization, and no resulting establishment of the parasite. A similar relationship held true at several other release points.

The actual times of removal of the endoparasitic material from the controlled cold-storage rooms were determined by the period required for development of the parasite to the adult stage, in relation to the program for parasite liberation. The areas to be colonized were listed and the dates for liberations to effect synchronization with the host insect in its proper stage of development were determined from observations on the seasonal history of the host in previous years.

Owing to the brief developmental period required to produce adults from stored cocoons, synchronization of releases of these parasites was obtained by removal from cold storage at the time governed by the progress of host development in the season of release.

It was necessary to segregate the parasites from different points of origin during emergence. To accomplish this, the host material from each source was confined in an individual emergence chamber, four in all. These measured 6 feet long, 4½ feet wide, and 7 feet high. Three of them were built within an outdoor insectary, with double walls of pressed-wood board, except for one end, which was covered with a transparent, wire-imbedded, celluloidlike material. Each chamber was equipped with ventilators through which the air could be drawn out or forced in,

and electrical current was available for the operation of mechanical insect collectors. The daylight entering each chamber could be supplemented with artificial light from "daylight" bulbs placed outside the window of the chamber. Outdoor temperatures were relied on to regulate the development of the parasites except during periods of unseasonably cold weather, when heat was supplied by an electric heater. One parasite emergence chamber was constructed inside a heavily insulated room in which temperature and humidity could be controlled as desired. This emergence chamber was held at 80° F. and 70 percent relative humidity. All light supplied to this chamber was artificial.

Although as many as 585,000 larvae could be handled in one emergence chamber, about 200,000 was a more convenient unit. Larvae to be placed in the developmental chambers while still spun up in the packets were removed from the shipping boxes in which they had been stored, and these packets were arranged one layer deep in shallow trays measuring 14¼ inches wide by 20 inches long, and 1 inch high. Each tray (fig. 3), consisted of a wooden frame with a bottom of 4-inch-mesh wire cloth, the end of which was covered with a metal strip ¼ inch wide. Each tray held 20 packets of about 400 larvae each, or a total of 8,000 larvae. These trays were stacked in a double column in slots in a mobile rack (fig. 4). The racks were of two sizes but of similar construction. The smaller racks had a capacity of 36 trays, or 288,000 larvae, and the larger ones held 117 trays, or 936,000 larvae. However, in actual practice, only about 5,000 larvae were usually in the packets in any one tray; therefore the number of larvae handled per rack was greatly reduced.

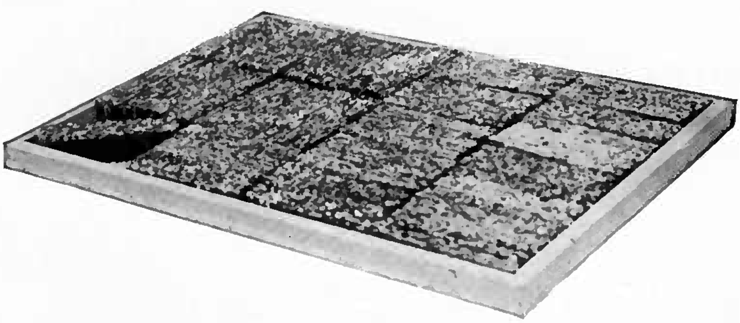

FIGURE 3.—Tray holding packets of European corn borer larvae in storage.

At the time of removal from storage, and approximately once a week during the developmental period, all packets in the trays were moistened. It was necessary to exercise considerable care in applying moisture, since a very high humidity with a high rising temperature (over 70° F.) caused the larvae to migrate. Such movement could be stopped quickly by lowering the humidity, even though this was accompanied by higher temperatures. In the emergence chamber, where temperature and humidity could be controlled as desired, there was no trouble from migration.

All parasites handled in the emergence chambers showed positive phototropic responses. As parasite and host adults issued,

they were drawn by either natural or artificial light to the front of the emergence chambers, where they were collected.

Moth Emergence

Most of the borer larvae placed in the emergence chambers pupated and large numbers of moths emerged. Since the presence of corn borer moths complicated parasite collection in the emergence chambers, it was important to note the moth-emergence trend. Moths began to emerge about 2 weeks after the larvae were placed in the emergence chambers, but did not

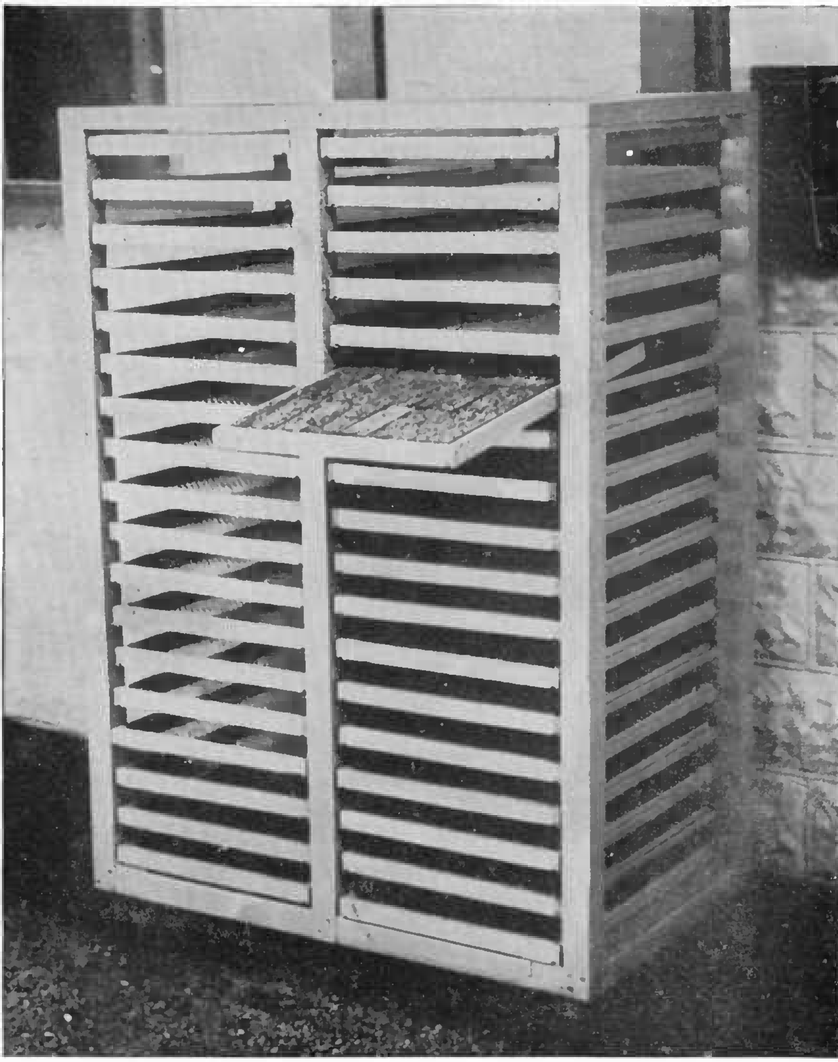

FIGURE 4.—Mobile rack holding trays of European corn borer parasite material.

become numerous until another week had passed. By this time most of the *Lydella stabulans grisescens* and a large portion of the *Zaleptopygus flavo-orbitalis* adults had emerged. Adults of *Horogenes punctorius* appeared while moth emergence was at its height. Since many of the host moths emerging in the chambers were known to be of different strains, and because of the possibility of the strain of any of the host adults differing from those present at the release points for which parasites were scheduled, particular care was taken that moths were not drawn into the shipping cans with the adult parasites. To insure this, it was necessary to remove the corn borer moths before collecting the adult parasites.

FIGURE 5.—Device for collecting and destroying European corn borer adults prior to collecting parasites in emergence chambers.

Since it was necessary to destroy the moths, they were collected by means of a modified electric vacuum cleaner (fig. 5) into a large metal can partly filled with oil. The suction of this collecting apparatus was ample for rapid collection of the moths and to force them into the oil. The nozzle used on the moth collector had a small aperture to enable the operator to pick out individual moths when adult parasites also were present. A recent improvement has been the installation of a central vacuum system piped to all emergence chambers. Moths are drawn to

a metal container in the laboratory basement. The same system has proved very useful for cleaning cages and for general sanitation.

Parasite Emergence

Adult parasites were collected from the emergence chambers directly into parasite-shipping cans by means of an electric collector (fig. 6), which consisted of a "hair dryer" modified by the addition of a zinc-reinforced celluloid casing to hold the parasite shipping can in place. The central vacuum system has also been utilized to draw parasite adults directly into shipping cans,

Figure 6.—Device for collecting parasites directly into a shipping container.

and where this system is available, it has proved very satisfactory. The parasite-shipping cans used were the same as the cans used for the importation of corn borer parasite material from the Orient. A 1½-inch hole was punched in the cover of each can. When the collecting can was ready for use, the end of a long celluloid nozzle, fitted into the cover of the removable casing, was inserted through the hole. A small quantity of excelsior was placed in each can to provide additional resting positions for the parasite adults.

Parasites were counted as they were collected, and individuals of only one species were drawn into each can. This procedure

facilitated the release of known numbers of any species. As they were filled, the cans were closed with corks and were then stored in cooled heavily insulated shipping boxes described by Bradley[7] until packed and shipped to the release points.

Since the parasite adults were drawn from the windows of the emergence chambers directly into the cans in which they were to be shipped, they were disturbed only once between the time of their emergence and their release in the field. The mortality due to handling was thereby reduced to a minimum.

In order to obtain an estimate of the approximate number and species of parasites to become available for colonization from stored material, samples of larvae were dissected prior to the developmental period. The general procedure of sampling was to remove and dissect 10 larvae from each of 5 packets taken at random from each shipping box. In those dissections, data on multiple-parasitization, superparasitization, and other biological phenomena were obtained.

It was found that 14 to 25 percent of the borers contained two or more larvae of the larvaevorid parasite *Lydella stabulans grisescens*. Biological studies have shown that usually not more than two larvae of *L. grisescens* can mature and emerge from a single host larva. The supernumerary parasite larvae, exceeding two in any one host, were disregarded in calculating the number of adults to be expected. From 1 to 17 percent of the dipterous larvae were in the third instar. All other dipterous parasite larvae noted were in the second instar. No host larva containing more than one *Horogenes punctorius* was found, and all of this species were in the first instar. Larvae of *H. punctorius* and dipterous larvae were found in the same host larvae. Of the dipterous larvae found within the borers, 1.1 percent were dead, as were 3.5 percent of the larvae of the *H. punctorius*. When *L. stabulans grisescens* and *Zaleptopygus flavo-orbitalis* were found in the same host larva, the *Z. flavo-orbitalis* larva was always dead, and where two larvae of *Z. flavo-orbitalis* were found in the same host larva, one of them was dead. All larvae of this species were in the first instar.

When estimating the number of parasites to be expected from any lot of host material, based on dissection findings, it is necessary to make certain deductions to compensate for mortality occuring during storage and development.

Table 9 presents data on parasite emergence from host material from different sources collected in 1934–37 and stored at Moorestown. This table shows greater mortality among individuals of some species than among others. *Zaleptopygus flavo-orbitalis,* an ichneumonid imported from the Orient, seemed to tolerate the artificial condition of storage and laboratory development better than any other species. Emergence of this parasite was probably close to 100 percent.

Horogenes punctorius was most adversely affected by the laboratory handling, and emergence averaged less than 50 percent

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[7] BRADLEY, W. G. A THERMALLY INSULATED UNIT FOR THE TRANSPORTATION OF ADULT INSECT PARASITES. U. S. Bur. Ent. and Plant Quar. ET–77, 3 pp., illus. 1936. [Processed.]

TABLE 9.—*Emergence of parasites from host material at the Moorestown, N. J., laboratory in 1935, 1936, and 1937*

Source of material	Larvae	*Lydella stabulans grisescens*				*Horogenes punctorius*			
		Borers parasitized	Estimated parasites available	Parasites obtained	Efficiency of species	Borers parasitized	Estimated parasites available	Parasites obtained	Efficiency of species
	Number	*Percent*	*Number*	*Number*	*Percent*	*Percent*	*Number*	*Number*	*Percent*
Pietrasanta, Italy, Europe, 1934–35	1,141,393	18.6	212,299	135,050	63.6	3.3	37,666	8,457	22.4
Miyakonojo, Japan, Orient, 1934–35	134,592	28.9	38,897	13,431	34.5				
Subtotal, 1934–35	1,275,985	19.7	251,369	148,481	59.1	3.3	37,666	8,457	22.4
Domestic collection, 1935–36	166,988	4.3	7,180	6,639	92.5	15.0	25,048	15,715	62.7
Orient, 1935–36	102,444	20.7	21,206	9,897	46.7				
Subtotal, 1935–36	269,432	10.5	28,290	16,536	58.5	15.0	25,048	15,715	62.7
Domestic, 1936–37	191,265	1.5	2,869	2,239	78.0	12.8	24,482	10,149	41.4
European:									
Small larvae 1936–37	4,750	6.0	285	71	24.9	6.0	285	98	34.4
Large larvae 1936–37	80,530	6.5	5,234	5,468	100.0	.5	403	732	100.0
Subtotal, 1936–37	276,545	3.0	8,296	7,778	93.7	9.1	25,166	10,979	43.6
Total 1934–37	1,821,962	15.8	287,970	172,795	60.0	4.8	87,884	35,151	40.2

TABLE 9.—*Emergence of parasites from host material at the Moorestown, N. J., laboratory in 1935, 1936, and 1937—Cont.*

Source of material	*Zaleptopygus flavo-orbitalis*				*Chelonus annulipes*				Total			
	Borers parasitized	Estimated parasites available	Parasites obtained	Efficiency of species	Borers parasitized	Estimated parasites available	Parasites obtained	Efficiency of species	Borers parasitized	Estimated parasites available	Parasites obtained	Efficiency of species
	Percent	*Number*	*Number*	*Percent*	*Percent*	*Number*	*Number*	*Percent*	*Percent*	*Number*	*Number*	*Percent*
Pietrasanta, Italy, Europe, 1934–35									21.9	249,965	143,507	57.4
Miyakonojo, Japan, Orient, 1934–35	3.2	4,307	3,591	83.4					32.1	43,204	17,022	39.4
Subtotal, 1934–35		4,306	3,591	83.4						293,168	160,529	54.8
Domestic collection, 1935–36									19.3	32,228	22,354	69.4
Orient, 1935–36	10.8	11,064	14,847	100.0					31.5	32,270	24,744	76.7
Subtotal, 1935–36		11,064	14,847	100.0						64,498	47,098	73.0
Domestic, 1936–37									14.3	27,351	12,388	45.3
European:												
Small larvae, 1936–37					70.0	3,325	1,839	55.3	82.0	3,895	2,008	51.5
Large larvae, 1936–37					0	0	193	0	7.0	5,637	6,393	100.0
Subtotal, 1936–37						3,325	2,032	61.1		36,883	20,789	56.4
Total 1934–37		15,371	18,438	100.0		3,325	2,032	61.1		394,550	228,416	57.9

for the three seasons. Emergence of *Chelonus annulipes* and *Lydella stabulans grisescens* each averaged about 60 percent. From a consignment of 11,809 cocoons of *Microgaster tibialis* received from Europe in the winter of 1935–36, a total of 9,062 adults, or 76.7 percent, were reared.

Lydella stabulans grisescens was always the first to appear in the emergence cages. The duration of the hibernation period made some difference in the length of the period elapsing between the removal of the hosts from cold storage and the appearance of the parasite adults. As with other parasites, the longer the storage period was extended the sooner the adults appeared after incuba-

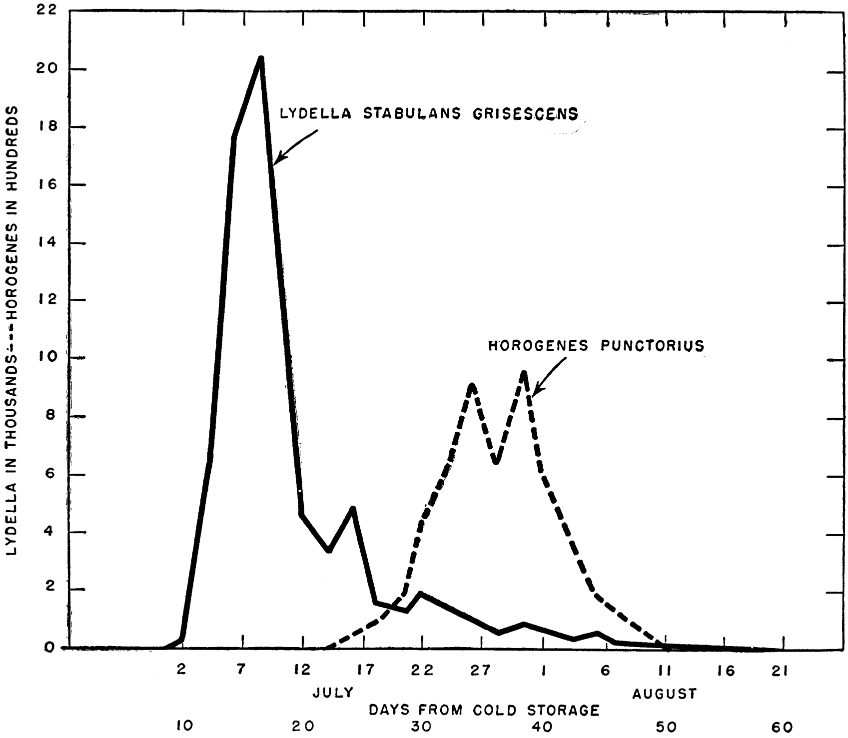

Figure 7.—Emergence trends of *Lydella stabulans grisescens* and *Horogenes punctorius*, season of 1935.

tion was started. In general, however, emergence of *L. stabulans grisescens* started within 13 to 18 days after removal from cold storage, reached a maximum very quickly after emergence started, or from 16 to 20 days from the beginning of incubation, and also declined very rapidly. Over 85 percent of the adults of this species issued within 14 days after emergence began. There was a more or less pronounced tendency in certain lots toward a second peak 3 to 5 days after the first. A few adults continued to emerge daily over a long period. Some appeared as late as 45 days after adult emergence started.

Emergence of *Horogenes punctorius* began 25 to 43 days after removal from cold storage, and the peak was reached from 10 to

16 days later. Adult emergence fell off more slowly than was the case with *Lydella stabulans grisescens*. Adults continued to appear for over a month after emergence began.

Under the environmental conditions prevailing at the Moorestown, N. J., laboratory, emergence of *Zaleptopygus flavo-orbitalis* adults began within 18 to 25 days after removal from storage, and the peak of emergence was 4 to 7 days after the first adults

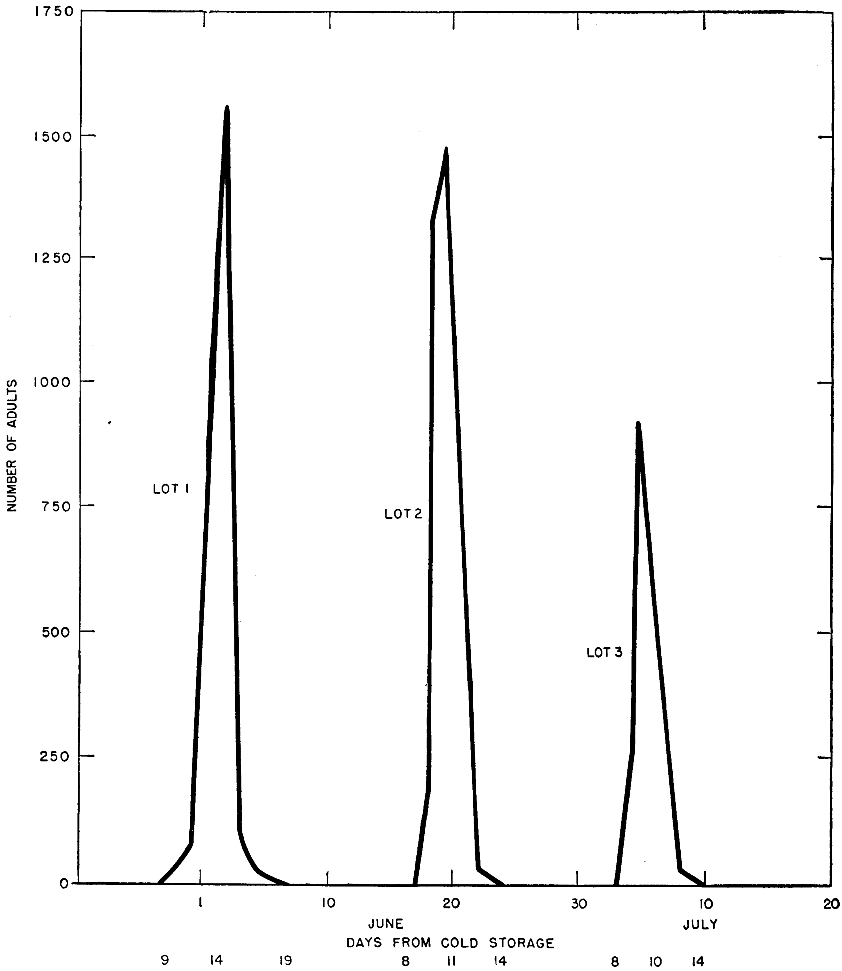

FIGURE 8.—Emergence trends of *Microgaster tibialis*, 1936.

appeared. Males emerged 3 days earlier on an average than the females, a fact which would account for a second peak emergence 3 or 4 days after the first. The peak of *Z. flavo-orbitalis* emergence occurred about 10 days after the peak of *Lydella stabulans grisescens* emergence from the same host material. Under similar conditions, *Z. flavo-orbitalis* emerged before *Horogenes punctorius*.

The peak of emergence of the egg-larval parasite *Chelonus annulipes* occurred 10 days after the start of emergence and 49 days after removal from cold storage.

The emergence periods and trends for two parasites stored and reared at Moorestown are shown in figure 7.

The cocoons in which the parasite *Microgaster tibialis* spends the winter were brought from storage and handled during the developmental period as described by Arbuthnot and Baker.[8] At the Moorestown laboratory adults started to emerge 8 or 9 days after the cocoons were removed from storage, and the emergence peak was reached 10 to 14 days later. Emergence was practically complete by the fifteenth day after removal from storage. The emergence from each of the three lots of cocoons handled during the 1936 season is shown in figure 8.

Post-Emergence Examination of Host Material

After the emergence of parasites had ceased, samples of the material still remaining in the emergence chambers were examined, to obtain additional information on the success of the program and for any indications that might lead to improved technique in rearing operations. In these examinations the extent of mortality, host pupation, parasite puparium and cocoon formation, and other factors that might have affected the parasite material were noted.

Several features of interest were revealed by these examinations. It was apparent that high temperatures caused increased mortality among the host larvae. In material handled during 1937, the lots that escaped the excessively high July temperatures of that year showed considerably lower mortality than those undergoing development during that period. It was also shown that there was greater mortality in the more heavily parasitized than in the lightly parasitized lots of larvae segregated and handled under identical conditions. This comparison was possible in the larvae parasitized by *Chelonus annulipes,* since the parasitized and unparasitized larvae could be roughly segregated because normally parasitization by this species has a stunting effect.

During the storage period of 1936–37, lots in which parasitization by *C. annulipes* averaged 70 percent suffered a winter mortality of 11 percent; whereas in lots from the same source in which parasitization averaged only about 12 percent the mortality was only 3.4 percent. Although similar observations usually are impossible with parasites whose presence does not change the outward appearance of the host larvae, it seems probable that the mortality of larvae parasitized by such species is higher than that of unparasitized individuals, and that parasites cause a host mortality not generally accredited to them.

In the two years in which material from the Orient was handled at Moorestown, the mortality among these larvae was much lower than among larvae from other sources. The cause of this difference is not definitely known. Apparently, in 1935 the oriental larvae in general were more mature than those imported from

[8] See footnote 6, p. 16.

Europe, which may account for the difference. During that season the mortality of European larvae was almost twice as great as that of oriental larvae. In 1936 the mortality of the domestic larvae was over 90 percent greater than of the oriental. In both years the packets containing the oriental larvae were impregnated with beeswax, whereas those containing the European material in 1935 and the domestic material in 1936 were handled in untreated packets. Mortality of larvae in the puparia and cocoon stages was very low for all species, averaging not over 8.5 percent in any case. Tables 10 and 11 give a comparison of data relative to host and parasite material examined after the emergence seasons of 1935 and 1936.

TABLE 10.—*Host mortality of European corn borer parasite material at post-emergence examination, Morrestown, N. J., 1935–36*

Source of material	Host larvae		Host pupae		
	Living	Dead	Emerged	Living	Dead
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1935					
European	11.9	52.5	15.6	0.7	2.8
Oriental	7.7	18.6	48.3	2.0	.5
1936					
Domestic	3.2	28.5	48.9	.6	1.9
Oriental	.3	14.9	40.6	10.1	.3

TABLE 11.—*Emergence of European corn borer parasites at Moorestown, N. J., 1935–36*

Source of material	Puparia		Cocoons	
	Emerged	Unemerged	Emerged	Unemerged
	Percent	*Percent*	*Percent*	*Percent*
1935				
European	[1] 14.5 (18.6)	0.5	[2] 1.2 (3.9)	[2] 0.1
Oriental	11.9 (30.0)	8.1	[3] 3.8 (3.2)	[3] 0.1
1936				
Domestic	4.7 (4.3)	.2	[2] 11.9 (15.0)	[2] 2.6
Oriental	11.6 (19.4)	3.8	[3] 15.2 (13.2)	[3] 4.0

[1] Figures in parentheses refer to estimated original parasitization.
[2] *Horogenes punctorius.*
[3] *Zaleptopygus flavo-orbitalis.*

PARASITE SHIPMENTS

Because of the extent of the area over which the corn borer parasites had to be moved for colonization, it was necessary to use exceptionally efficient equipment and technique in shipping.

The large cloth-covered shipping cages illustrated by Jones[18] were later modified by fitting the interior with convolutions of cloth to provide additional resting surface for the parasites. This method of shipping in large containers had several disadvantages. Consignments of parasites of a number of different species, or

parasites of the same species intended for release at several liberation points, could be handled only in extremely bulky shipments or by releasing the parasites in a room near the liberation points and collecting them again in lots before taking them to the field. To obviate these objectionable features small cans similar to those used for importing host larvae from Europe and the Orient were used for shipping parasite adults. (See Importations from Europe, p. 4.)

When first utilized for this purpose a small rectangular piece of ¼-inch-mesh hardware cloth, bent to form a hollow triangular wire prism, was fitted into the can to serve as a resting place for the adult parasites. Small sections of No. 3 absorbent cotton rolls, supported in the mesh, were saturated with water just before shipment. To prevent high mortality caused by low humidity, strips of moistened cheesecloth were wrapped around each can. Owing to the varied temperatures encountered during shipment, water frequently condensed on the metal within the cans, and many parasites were weakened or killed by being caught in the droplets. Later the wire support was dispensed with, and fine excelsior was substituted to afford resting surfaces for the adults and to reduce condensation of moisture.

After being wrapped in moistened cloth, each can was marked with the number and species of parasites contained in it. It was unnecessary to provide food or water other than in the moistened cloth wrapping. As many as 350 adults of *Lydella stabulans grisescens* could be shipped in each can, but only 200 adults of *Horogenes punctorius* or *Zaleptopygus flavo-orbitalis* and 250 adults of *Chelonus annulipes* were placed in one can.

Three methods of transportation were used in moving parasites from the rearing laboratory to the point of release. For long-distance shipments involving more than 24 hours of travel time, railway, boat, and aeroplane were used. For all other distances, railway express was the medium, except for release points in the vicinity of the rearing laboratory, for which transportation was by automobile. An iced shipping box described by Bradley[9] was used for all rail, rail and boat, and automobile shipments, to overcome the limited shipping schedule of the refrigerated express.

Parasites to be shipped by air were confined in the standard 3 by 5-inch screen-sided cans, each of which was wrapped in moist cheesecloth and enclosed in a corrugated-cardboard carton. A number of these cartons were packed in a larger corrugated-paper carton. The maximum number of cans per package shipped by air was 32. As there were 250 adults per can, this made a maximum of 8,000 per package. The larger carton was first wrapped with a layer of cloth, and then with a layer of absorbent cotton, which was covered with an outside layer of cloth. The loose ends of this cloth were stitched. The layer of cotton was dampened and the package was placed in a cold-storage room at 40° F. for 3 hours before being shipped.

A heavy manila envelope containing the bill of lading to facilitate delivery of the package at the destination, was tied to the package. A tag containing the address and a shipping permit was

[9]See footnote 7, p. 23.

attached, and the package was delivered to the express company just in time to permit the placing of the shipment on the scheduled plane.

Five species of corn borer parasites have been shipped by air express. Where plane schedules have been maintained this type of service was satisfactory, but unavoidable delays were so frequent, over a shipping period of 4 years, such transportation did not prove to be satisfactory.

To find a desirable substitute for air shipments to points more than 24 hours distant by rail, two methods were tested in 1938. (1) Shipments for which part of the travel was across water consisted in transporting the material in an insulated iced shipping box via railway express to the export point, and thence by boat in the same container, under refrigeration, to the point of deliv-

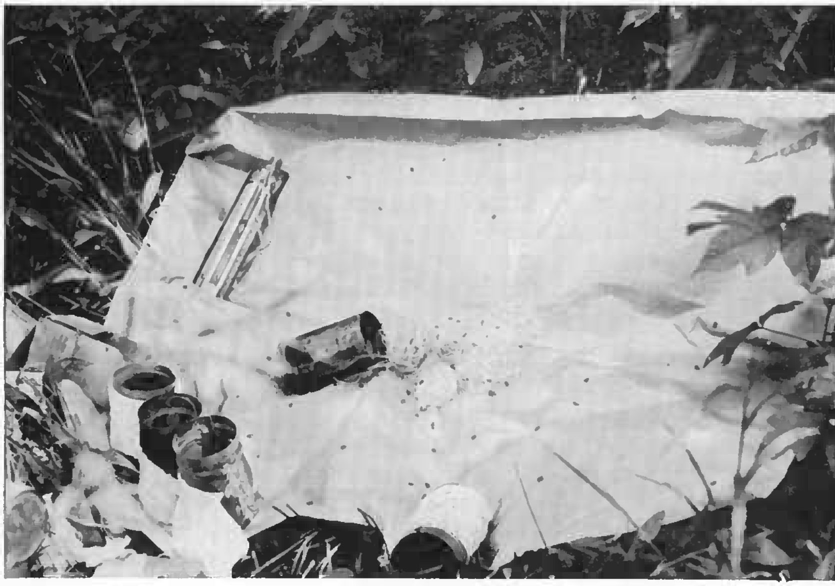

FIGURE 9.—Liberating European corn borer parasites near shrubbery at the edge of a cornfield.

ery. A consignment of 2,000 *Chelonus annulipes* adults was shipped by this method on June 21 from Toledo, Ohio, to San Juan, P. R. The box was sent by railway express to New York, where it was placed on board ship for San Juan. The box was re-iced at New York, and again on receipt at San Juan. The total elapsed time between the date of shipment and the last release in the field was 7 days, and the mortality was only 2.1 percent. (2) In shipments entirely by rail directions for re-icing after 15 hours of travel were attached to the top of the box.

A test lot of parasite material was sent from Toledo, Ohio, to New Orleans, La., a distance involving more than 24 hours of rail travel. This method resulted in a mortality of only 0.2 percent from the time of shipment to field release in Louisiana. Shipments in insulated iced boxes via railway express were not only

reliable but also conducive of low mortality. During the period 1935–38 nearly a quarter of a million parasites were transported by this means and the average mortality among all species was less than 2 percent.

At the receiving points the box containing the parasites was usually re-iced and then taken to the field. At the liberation point, cans containing the requisite number of adults were removed from the box and taken to the windward edge of the field, usually in the shade of overhanging bushes or trees. The covers were removed and the cans were laid on the ground to permit voluntary egress of the adults (fig. 9). Records of meteorological conditions, ecological factors of the environment, and the condition of the adults were taken at the time of release.

The parasite shipments showing the lowest mortality rate were taken to the field from the rearing laboratory via automobile, the adults being again packed in iced shipping boxes as for rail transportation. The mortality counts included all the adults that died during collection and en route to the actual point of release in the field. A few canfuls of adults were allowed to escape in a cage at the laboratory and then were re-collected, and it was found that much of the mortality was the result of injury during collection. It was concluded that the mortality during actual shipment by all methods other than air express was less than 1 percent for all species handled during the 4-year period.

COLONIZATION AND SAMPLING METHODS

Liberation Procedure

Beginning with the first releases of three species of imported parasites at Watertown, Mass., during the period 1920–29, parasites were liberated in certain localities designated as test points. The objective was to test various environments as to the ability of the parasites to establish[10] and maintain themselves. The rate, direction, and extent of dispersion at the test points were studied and, where possible, the seasonal history of the parasites that had become permanently established was investigated. As increased numbers and species became available, additional releases were made at the original locations and at new ones.

In 1928, because of the natural spread and increase in corn borer populations along the borders of Lake Erie and Lake Ontario and southward from New England, more extensive preparations for testing and distributing imported parasites were made, and a systematic colonization program was planned. In formu-

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[10] In this discussion and in future references to the field status of parasites, the term "initial establishment" denotes the recovery of the parasites from the host generation present in the field at the time of release. It signifies that the parasite contacted the host in a stage favorable for attack and that parasitization was sufficient to be measured by the means employed. It implies nothing as to the status of the parasite after the completion of one annual cycle. "Establishment" means that the parasites not only became initially established in the environment but survived through more than one annual cycle of the host without being supported by other releases. A parasite is classified as being on a "maintenance" basis when its existence in the environment appears to be permanent.

lating and executing this program, obvious sectional differences and the specific environmental requirements of individual species were considered.

The principle of introducing all available primary parasites has been followed in all the colonization activities. H. S. Smith (*33*), in discussing multiple parasitization, has shown that when competition between species exists the final level of parasite population will be higher when all species are utilized. Smith says: "* * * on theoretical grounds, as well as on the data so far available, the policy of entomologists in introducing all available primary parasites of an injurious species is justified."

SELECTION OF COLONIZATION POINTS

In the early phases of the parasite colonization program it was impossible to determine the most satisfactory environments for the different imported species; therefore the locations for the releases were selected on a geographic basis as the best way of insuring the inclusion of the major environmental factors.

The specific point of release in each major geographical division was determined by a survey of the corn borer populations in the different localities. That township was chosen in which the borer concentration was highest or in which the borer population equaled or exceeded that of any other locality. The selection of the point of release within the township was governed by the environment.

At most of the colony sites the releases were made at a single point. At some sites, however, not all the parasites were liberated in the same field, but were distributed in a number of fields in the same vicinity. At a few locations, notably those in Perry Township, Wood County, and Damascus Township, Henry County, in Ohio, the Cattaraugus Indian Reservation in New York, and in eastern Massachusetts, the group type of release was used. Some of the adults were liberated in fields within approximately 10 miles of the center of each area but no better establishment resulted from group-type releases than from single-spot releases.

In selecting localities adequate protection, food, and water were considered of primary importance. The exact location of a release site may have been chosen because of a water supply in a stream, swamp, or lake. Wood lots or areas overgrown with shrubs offer potential protection. The presence of a variety of flowering shrubs, weeds, or trees, as a possible source of food for adult parasites, might mean the difference between successful or unsuccessful establishment of a species (King and Holloway, *19*). Typical environments selected for the release of corn borer parasites are shown in figure 10. The importance of these protective factors decreases, however, as the synchronization increases between the release of parasites and the appearance in the field of host stages suitable for parasitization.

In the early stages of the program the plan to release parasites in the most heavily populated section of a geographical division was modified by observing a minimum distance of 25 miles between colony sites, to prevent overlapping of dispersion. All the test points were sufficiently isolated so that reliable information

could be obtained on the rate and direction of spread of parasites, population fluctuations after various types of release, and efficiency of the different species in control of the borer.

When the main objective was the distribution of a species throughout an infested area, instead of making test releases, colony sites were selected about as for test points, but the deter-

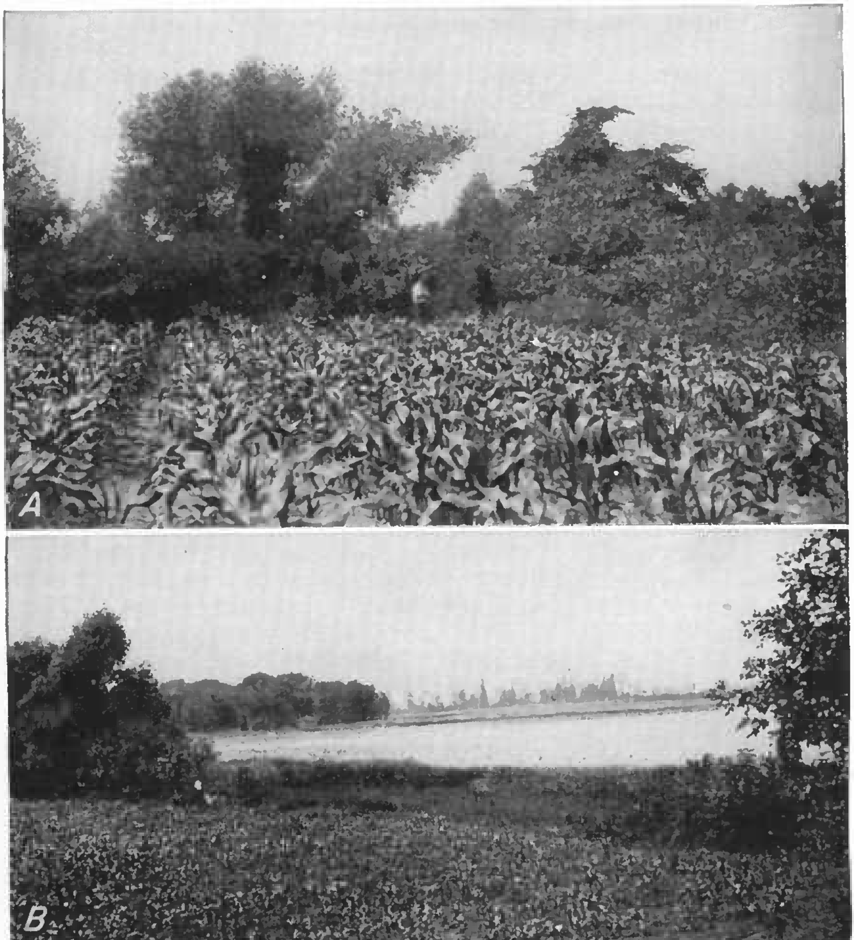

FIGURE 10.—Typical environments for release of European corn borer parasites: *A*, Edge of cornfield bordered by woods; *B*, near water at edge of cornfield.

mining factors were derived from biological studies of the parasite and its reactions to field conditions. The distance between colony sites was definitely established from known data on distance and direction of spread, the number of individuals available for distribution, the size of the colony necessary for initial establishment, and the size of the area to be covered by the colony.

The total number of distribution points was arbitrarily controlled by the size of the total infested area and by the number

of parasites available for colonization. Occasional releases were made in a locality where the environmental conditions were significantly different from those generally prevailing, to determine whether the conditions were favorable for both the host and the parasites. There was also the chance that such a locality might serve as a chronic source of reinfestation of adjacent areas, and that a parasite population might build up enough to offset the borer menace and to furnish a permanent source for spread into adjacent territory. Numerous special colonies were established in restricted localities to obtain necessary information, such as adequate size of colonies, possible benefits to be derived from synchronization, and other variations from standard liberation technique, which might improve the efficiency of parasite handling.

Each season the comparative values of the different colonization sites were considered carefully as to the number and concentration of borers present, the probable direction of spread of the borer, and the relative importance of the section as to corn production. The sites were then classified, the more favorable ones being colonized completely with all available species of parasites. The only restriction that limited the testing of any parasite throughout the entire infested area was the number of adults available for colonization. This number was divided into units sufficiently large to insure establishment and maintenance, where the parasites were capable of surviving in the environment.

DETERMINATION OF THE SIZE OF COLONIES

An arbitrary colonization unit for all species was set at 1,000 females, plus males in proportion to their normal sex ratio. Although establishment of some species might be obtained from smaller units, and considerable variation existed in the colonization requirements of the various parasites, the arbitrary number of 1,000 females was considered a practical working unit. It was shown that excellent initial establishment of some species could be obtained through the release of smaller colonies; however, no colony of less than 500 individuals was considered adequate for establishment. Once fixed, the determined number was used in all subsequent liberations, whether for testing in the selected environments or for distribution to supplement natural dispersion where the rate of spread was so slow as to justify further colonization.

PERIOD OF RELEASE

In determining the number of years during which releases should be made at any one point, several factors were considered before a formalized procedure was adopted. Because of the lack of information on the adaptability and efficiency of corn borer parasites in new environments, and because of the uncertainty of climatic conditions, it is of primary importance that releases be made in more than one year. Adequate initial establishment is necessary for the parasite to have a reasonable chance of survival. Once firmly established and included in the natural environmental complex, a species would be better prepared to with-

stand adverse circumstances than would a few hundred newly introduced individuals. Consequently, it was decided that if the capability of a species did not become apparent after the original liberations, releases should be repeated.

It was obviously unwise to continue placing adults of the same species in the same locality indefinitely because (1) it would interfere with the early appraisal of the relative merits of the parasites, which was necessary for the most effective and economical distribution program; and (2) because of the limited numbers of parasites available, as compared with the large size of the infested area over which colonization was desirable. Since it was necessary to colonize some 150,000 square miles of infested territory having varied environmental conditions, it was unwise to restrict the number of colonization points unnecessarily.

An arbitrary period of 3 years of release at any one point was adopted as the standard for all species. Consecutive years were preferable, although not always practical, because the supply of adults available for colonization varied from one year to another. Whenever experience revealed defects in colonization technique, the species affected was considered as untested and was released 3 more years at the same site.

It often happened that a species previously tested thoroughly throughout the entire borer-infested area, without showing promise, still appeared in the importations, having been taken incidentally in the foreign collection of other species. Such species were again utilized as untested after a 3-year lapse following standard liberations at any point. This procedure provided for the testing of the immediate effects of the different environmental conditions that might have prevailed in the test localities during the second release period. As soon as field surveys showed that an introduced species was present at a test location in sufficient numbers to indicate establishment, releases of that species were discontinued.

At locations where liberations had been discontinued because of sufficient initial establishment, and where the parasite subsequently failed to survive, the parasites were listed as untested after a 3-year period of failure to recover them. With respect to that locality the parasite was returned to the program as an untested species.

To meet the requirements of individual species or the variations in host concentration and dispersion, some adaptations were made in the operation of the colonization program. Certain species were released in some locations in more than 3 years. With all such species, except *Microbracon brevicornis,* this procedure was followed because the numbers available for colonization in certain previous years had been considered too small for an adequate test. With *M. brevicornis,* in view of the large numbers available for liberation and its consistent failure to become established, it was deemed advisable to extend the arbitrary 3-year liberation period at a few points to increase the chances of liberating the parasite under the most favorable environmental conditions.

An aditional complication in the program resulted from the importation of apparently identical parasite species from both Europe and the Orient, for example, *Macrocentrus gifuensis,*

TABLE 12.—*Number of releases of imported parasites of the European corn borer in the United States, 1920–40*

State	*Aplomya mitis*	*Apanteles* sp.	*Apanteles thompsoni*	*Bracon atricornis*	*Campoplex multicinctus*	*Campoplex pyraustae*	*Chelonus annulipes*	*Zaleptopygus flavo-orbitalis*	*Campoplex alkae*	*Eulophus viridulus*	*Exeristes roborator*
Connecticut	178		21,268	12		1	54,105	1,483	1,057	17,200	
Illinois											2,302
Indiana	8		5,700				6,735		5,161	6,671	22,905
Maine											
Maryland							1,981				
Massachusetts	514	388	69,139	127	1,129	1,697	16,010	6,762	28,526	84,786	54,957
Michigan	395		34,837				6,363		24,075	44,037	86,607
New Hampshire											
New Jersey							8,681	1,192			
New York	463	3	51,106		61	16	137,821	1,109	9,279	55,755	40,050
Ohio	1,664		52,505		357	38	22,952	5,145	36,398	101,648	87,826
Pennsylvania	20		5,774						550		20,119
Rhode Island	188		11,756	211	123	47	7,523	1,014	4,636	7,446	
Vermont							6,982				
Virginia							10,777	2,971			
Total	3,430	391	252,085	350	1,670	1,799	279,930	19,676	109,682	317,543	314,766

State	*Horogenes punctorius*	*Lydella stabulans grisescens*	*Macrocentrus gifuensis*	*Meteorus nigricollis*	*Microbracon brevicornis*	*Microgaster tibialis*	*Nemorilla floralis*	*Phaeogenes nigridens*	*Pseudo-perichaeta erecta*	*Pseudo-perichaeta roseanae*	Total
Connecticut	6,882	42,723	23,970		4,952	7,101	533	1,620	193	7,154	190,432
Illinois					3,635						5,937
Indiana	6,588	25,335	4,416		105,109	8,985				8,526	206,139
Maine		1,927									1,927
Maryland		5,365			1,616						8,962
Massachusetts	30,938	92,087	82,444		1,084,590	84,689	371	21,885	844	64,755	1,726,638
Michigan	11,987	121,219	40,790		534,334	81,747		3,933		17,896	1,008,220
New Hampshire	593	5,569									6,162
New Jersey	2,351	7,661	23,073		11,857	1,809		4,037			60,661
New York	16,545	122,153	62,372		354,265	34,752		569	4	29,743	916,063
Ohio	44,065	217,448	135,778		587,583	138,585	843	8,306	499	32,334	1,473,974
Pennsylvania	707	11,588	9,006		127,305	6,842		347		3,800	186,058
Rhode Island	14,572	35,293	39,182	8		19,740		12,037		9,305	163,081
Vermont	2,279	9,813									19,074
Virginia	1,678	3,956			5,157	3,199					27,738
Total	139,185	702,137	421,031	8	2,820,403	387,449	1,747	52,734	1,540	173,513	6,001,069

TABLE 13.—*Number of corn borer parasites shipped to Canada, 1923–40*

Species	1923	1924	1925	1930	1931	1932	1933	1936	1938	1939	1940	Total
Apanteles thompsoni				1,090	6,600	7,000	225					14,915
Chelonus annulipes				2,020	246	4,070	1,453					7,789
Zaleptopygus flavo-orbitalis						1,373	160					1,533
Campoplex alkae				43	7,225	8,737	654					16,659
Eulophus viridulus					6,200	25,791	1,760					33,751
Exeristes roborator		226	66									292
Horogenes punctorius				4,195	5,849	12,459	2,575	600	200	27	330	26,235
Lydella stabulans grisescens				33,279	22,158	18,670	15,474					89,581
Macrocentrus gifuensis				3,297	2,531	24,471	33,244		3,565	9,000	6,005	82,113
Microbracon brevicornis	2,714											2,714
Microgaster tibialis					6,251	4,500	7,384					18,135
Nemorilla floralis						143						143
Phaeogenes nigridens						4,600	25					4,625
Pseudoperichaeta erecta						82						82
Aplomya mitis				211			42					253
Pseudoperichaeta roseanae				4,121	1,863	1,280	140					7,404
Total	2,714	226	66	48,256	58,923	113,176	63,136	600	3,765	9,027	6,335	306,224

Lydella stabulans grisescens, and *Horogenes punctorius*. Although within the species the adults of different origin could not be distinguished taxonomically, it was possible that they might differ biologically. To avoid possible confusion, certain districts were reserved for colonization of oriental species when apparently identical species from Europe were being colonized.

Frequently the spread and increase of the corn borer in an important corn-growing county necessitated the placing of that county higher in the weighted list of colony sites and in colonizing parasites in it before completion of the prescribed 3-year test period at older locations. To make releases at some of these new locations, it often became necessary to curtail the program at some of the older and less important sites.

From the time of the first release in 1920 through 1940, approximately 6 million parasites were released in the United States. The species and the numbers of individuals released in each State are shown in table 12.

Throughout the colonization program close cooperation has been maintained between the Canadian Department of Agriculture and the U. S. Bureau of Entomology and Plant Quarantine. Parasites have been forwarded to Canada for breeding and for field release (table 13).

Field Sampling Procedure

RELATION OF SAMPLING TO PARASITE FIELD STATUS

As a guide in planning and conducting further importation, breeding, liberation, domestic collection, and redistribution, it is necessary to have data on the biology, establishment, survival, multiplication, efficiency, rate and direction of dispersion, and fluctuations in population of imported parasites that have been colonized under various environmental conditions. Fundamental sampling problems are involved in deciding on the procedures to be followed in obtaining this information.

The relation of parasite liberation to intensity of parasitization must be carefully considered when any sampling system is constructed, since sampling immediately after current releases may yield results quite different from those obtained by sampling colony sites not supported with current releases. This situation is further complicated by the continuous introduction of species not previously released at the different sites. In the natural course of liberation procedure, additional species are tested at sites that previously received releases of other species. This condition resulted in not only a different lapse of time between liberation of different species but also in an introduced variation in their field status. Since this variable time factor alone may have an important bearing on the different influences being studied, sampling methods must be so devised that suitable analyses can be made of field data pertaining to the reaction of individual species.

In the infested area in the United States 21 different species of imported parasites having specific requirements as to libera-

tion technique and optimum sampling time, were colonized. For instance, an exceptionally high initial establishment of a species might be obtained directly from liberation technique, but this condition would not be a true index of the ultimate efficiency of the parasite. The influence of initial establishment imposes itself on the results of the survey and must be analytically separable from other data that reveal more truly the status of those parasites which, following a lapse of time, have more nearly attained a stable part of a given locality's parasite population. Both types of information are indispensable and data must be available to permit the proper evaluation of each.

With these objectives in mind, the immediate consideration in devising the sampling method was the individual species, rather than the combined status of all species. For lack of available funds and personnel, it was impractical to attempt to apply the optimum technique to serve each desired objective. There were at least 10 specific subjects on which immediate information by some form of sampling was desired, and these applied equally to each of the 21 imported species colonized. The determination of the status of native parasites was an additional complication.

PRINCIPLES OF SURVEY SAMPLING IN RELATION TO STATISTICAL INTERPRETATION OF RESULTS

The foregoing discussion has treated the general objectives toward which parasite field sampling should be directed. Methods of sampling based on the biology of the parasites, the area to be covered, and the funds available, and conforming to rigorous mathematical principles, were developed.

The samples must provide the following statistical information: (1) A measure of the condition being sampled, and (2) a measure of the error involved in measuring the conditions. In plot experiments the conditions being measured and compared are the differences between treatments or varieties, and the principles of replication, randomization, and local control are used to mitigate the errors due to soil heterogeneity and other factors. In field surveys the conditions being measured and compared are the populations of hosts or parasites in specified areas, and the same principles may also be used to mitigate the errors due to the variability of the insect populations in the different sections of an area.

The difficulties arising from the variability of the insect populations within an area may be overcome by distribution of multiple samples. Other factors being equal, the greater the number of samples taken the more nearly will the average tend to approach the true condition of the area. It may also be assumed that the variability of the insect population, like the soil variability in plot experiments, cannot be regarded as distributed at random over the whole area, but is to some extent systematic, so that neighboring sections are, on the average, more alike than sections farther apart. The principle of local control can therefore be utilized by taking the samples in sections systematically distributed in the area according to some plan. Within each section the samples must be taken at random. This section may

be the field nearest the center of each section, if the sections are placed at random insofar as conditions permit. Samples should not be taken from the same place in successive years.

The principle of local control is thus used to the greatest possible extent by dividing the area into as many sections as there are samples to be taken. However great the variability between sections, the actual error of estimate of the mean for the area will be due to the variability within the sections alone. This sampling variability or error can be estimated only by using two or more samples within each section. Each sample, however, is placed individually in a section and combined later in multiple-sampled sections for the determination of the sampling error. For each of the many diverse problems listed previously, a valid solution should exist and be recognizable, if the sampling has been carried out correctly.

The principles of survey sampling are equally applicable to the placement of colony sites within the area and to the placement of samples about the colony sites or of subsamples in the fields. Each colony site may be regarded as a sample of the adaptability of the environment to the species of parasites in the area as a whole. The more dispersed these species are, within the limits of practicability and the possibility of recovery sampling, the greater likelihood there is of getting a representative sample of all conditions in the area.

Owing to the great extent of the area, the diversity of conditions, and the limitation of material, it was deemed advisable to establish the colony sites in selected environments, rather than at arbitrary intervals regardless of conditions. The borers taken at each colony site constituted a sample of the native parasites in the area, as well as of the introduced species. In analysis for some purposes, such as the comparison of the means of general areas from year to year, these samples corresponded to the section-random method of sample placement around colony sites, described later, in which full advantage can be taken of the principles of replication, randomization, and local control. For other purposes of analysis, such as comparison of means of parts of the general area in the same year, these samples correspond to the unrestricted-random method of placement about colony sites that utilizes the principles of replication and randomization, but not the important principle of local control.

For the placement of samples about colony sites, three methods were tested in the field and their relative merits critically scrutinized in the light of these principles of survey sampling in the development and final selection of a suitable technique: (1) The strip method; (2) the unrestricted-random method; and (3) the section-random method, which conformed rigidly to the principles of replication, randomization, and local control.

The first, or strip method, represents an extreme of arbitrary restriction which involves laying out definite radiating lines, or transects a delineated environment from a common center—in this case the liberation point—and taking samples at uniform distances along these lines. The lines may run only in the cardinal-compass directions, or additional radii may be added as funds permit. This method may be adapted to specific objectives,

such as parasitization along natural or artificial lines—rivers, lake fronts, prevailing winds, and highways—but is not suited to general sampling and does not measure the true status of the parasites. In addition to the high degree of arbitrary restriction employed, undesirable unbalanced concentration of sampling occurs near the immediate point of release. This difficulty could be obviated by additional radii beginning at successive distances from the liberation point. Such a procedure, however, would merge into the polar-coordinate system of placement, developed for use with the section-random sampling plan.

The unrestricted-random method represents an opposite extreme to the strip method in the operation of a standardized field-sampling technique. By this method the area to be sampled is divided into convenient sections of equal size, designated by consecutive numbers. From the total number of sections included in the area being surveyed, the numbers of the actual fields to be sampled are taken from Tippet's Random Sample Numbers (*38*), utilizing the particular series of random numbers applicable to the total number of samples that can be obtained in the area.

Regardless of the variation in type of the random-sampling method utilized, care must be taken to apply succeeding series of numbers to the separate areas in any one year and succeeding series to identical areas in consecutive years. While this method insures a desirable randomness and has many advantages, it has one serious limitation—the possibility that so great a randomness in taking samples might miss certain sections of the area being sampled and that the sections missed might have yielded illuminating data. Futhermore, this method, although utilizing the principles of replication or multiple samples and of randomization, almost completely lacks any utilization of the principle of local control. The random error, therefore, of the estimate of any mean from such samples would be influenced by practically the entire variability of the condition over the whole area, except for certain minor features of local control, such as distance from the liberation point. To obviate these deficiencies, the application of a more restricted sampling method was desired.

The section-random method has been developed to supply the need for this additional restriction. By this method the advantages of replication and randomness are fully utilized and the maximum of local control for the number of samples taken is obtained. This is the general scheme that formed the basis for the sampling plans in most surveys. It has sufficient flexibility to permit its application to a great diversity of conditions, and it is capable of modification, to provide for enlarged or retracted activities with the least possible disruption.

The first consideration in the application of the section-random method was the delimitation of the nature and objectives of the survey to be conducted and the number and size of samples that could be taken with the available funds and personnel. The area to be surveyed was divided into sections, the total number of sections to be utilized equalizing the total number of samples that could be taken in the area, and one sample was taken in each section. The sections and samples varied in size according to the stated objectives. The final scheme adopted for the sampling

of a given colony site was a compromise of the requirements of the numerous objectives.

Within each section the samples were placed entirely at random with reference to the conditions affecting the thing being sampled. This sample might be from the field nearest the center of each section, if the sections are laid out in an arbitrary manner about the liberation point, except with regard to distance. From year to year either the samples were allocated at random within the sections or the whole system was shifted. The method by which randomness could be accomplished was dependent on the size of the sections. Large sections could be subdivided into a number of smaller ones, and the immediate location could be determined by random drawings. The whole system could be rearranged so that the samples would fall in different locations in successive years. In shifting the samples to obtain year-to-year randomness the corresponding number of samples was placed at approximately the same average distance from the liberation point and balanced equally on all sides of it. Sufficient randomness of sample placement was usually obtained through normal crop rotation.

The section-random method, combined with a physical layout that conformed to the biological requirements, fulfilled the conditions of replication, randomization, and local control for supplying reliable estimates of area means; eliminated a large portion of the place variability; and allowed a valid estimate of the component of the variability remaining as the error of the estimate of the mean. These area means were of primary importance in parasite field studies because they formed the basis for the study of the ecological relation of the introduced species and for the evaluation of the relative effectiveness of parasites in controlling the corn borer. Replication or multiple samples increased the reliability of the estimates of the means and provided valid estimates of the random variability of the estimate of the means.

The increase in the reliability of the means with strict randomness is proportional to the square root of the number of samples. Systematic (section-random) placement of samples adds the feature of local control to replication and randomness, greatly increasing the efficiency of a given number of samples. Through local control the samples were distributed porportionately at determined distances and approximately balanced on all sides of the liberation point. The random variability applying to the estimate of the mean was reduced from the total place variability of the area under consideration to the sampling variability within sections by eliminating the variability between sections. The actual computed random variability of sampling became somewhat larger, because two or more sections were combined in the arithmetical estimation of the random component, but the real advantage in local control of placing each sample in separate sections still exists.

As the fields constituted the samples in the sections, the borer population in the field, in turn, was sampled. The principles of replication, randomness, and local control also applied to the sampling within the fields. The more reliable the estimate of the means of the fields the less the random variability of the

samples in the areas and, therefore, of the error of the area means for a given number of samples. The field sampling should be carefully planned to give replication, randomness, and local control; however, increasing the size of the field samples was not so effective as taking the equivalent increase in samples in more fields. The final specifications must therefore be guided by a balance with pertinent practical considerations. The samples in any level should, however, be uniformly distributed. Grouped samples must be considered as single samples, in that level, with subsampling.

THE SECTION-RANDOM METHOD APPLIED TO A PRACTICAL FIELD PROBLEM

The next consideration was the mechanical process to be followed in applying the section-random method to the specific areas selected for survey. The system generally used in comparable surveys is a rectangular-coordinate design suitable for obtaining abundance estimates of the entire area. Most of the colony sites to be sampled were relatively small, and information on the comparative biological responses of the different parasites at varying distances from liberation foci, in addition to parasite-population levels over the entire area, were needed; therefore some method other than the use of rectangular coordinates was desirable for parasite sampling. The polar-coordinate system eliminated the objections to the rectangular-coordinate system without decreasing the possibilities of gathering adequate data on control efficiency.

The polar-coordinate design is adapted to section-random sampling, and fulfills the statistical requirements of replication, randomness, and local control. Its actual application to colony sites is simple and subject to innumerable variations to fit specific demands. Since practical phases of the problem do not require differentiations of distances less than 1 mile, circles are inscribed on the map of the locality to be surveyed, each circle having a similar radius at least 1 mile greater than that of the preceding one, this being continued until the entire survey area is enclosed in the outer circle. A series of concentric rings of equal width is thus obtained. The total survey area in square miles, is divided by the number of samples to be taken, giving the approximate area to be included in each section to be sampled. Each ring area is then divided by the area previously determined to be included in each section, giving the total number of sections to be included in each ring.

The diagram must, of course, be adjusted to the scale of the map. The center of the system is located as near the actual point of parasite liberation as is practicable. Figure 11 illustrates a polar-coordinate design as drawn on a field map.

When the sections were outlined on a map of the area in which single samples were to be taken and the actual fields to be examined were located as outlined above, the samples were taken in accordance with the following procedure.

The observation unit for the parasite count was established at 100 borers, although a sampling unit of 50 borers appears to be satisfactory if the parasitization exceeds 15 percent. Fifty is

apparently the minimum number that can be expected to give reliable information, and has the added advantage of being a number that readily lends itself to the necessary manipulations of statistical analysis. Accordingly, one of these units was obtained from each of the sections comprising the polar-coordinate design. The samples within the sections were as nearly uniform in size as possible, in order to avoid giving some sections more weight than others, which might interfere with the solution and the interpretation of the results. The samples from each section were separate units representing discrete sets of conditions.

In the actual field collection, borers were taken wherever they could be obtained most conveniently, since observations showed that within fields the rate of parasitization was not affected by borer distribution. The varying distribution and intensity of

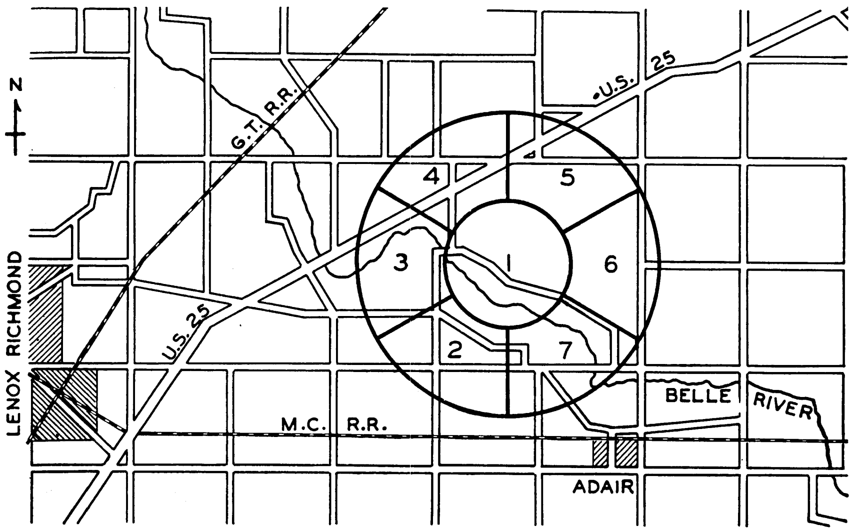

FIGURE 11.—A polar-coordinate design superimposed on a field map.

corn borer populations often required concentration of collections to restricted portions of the original field or, conversely, the expansion to include the entire section. If the complete quota of borers could not be obtained from one field, additional fields within the section were examined. If the complete quota of borers could not be obtained from the section, such borers as were obtained served as the sample. If no borers could be obtained within the section, that fact was noted and no further attempts were made to obtain compensating collections.

It was believed, however, that sampling was insufficient where initial establishment of a species was still extremely slight and no appreciable dispersion beyond the limits of the immediate influence of the liberation point had taken place. This situation was satisfied by fixing a sampling unit of 400 borers within the inner circle. These borers were taken from one field, arbitrarily selected by the collector as representing the best single possibility for supplying information on the establishment of the various species being tested. In this selection the investigator considered

distance and direction from release point, relation to possible protection, water and food supply, and stage of corn development as an index to borer population. One subunit, or subsample, of 100 borers was collected from each quarter of the field being examined. Each subsample retained its identity in the laboratory, since there was a reasonable expectation that higher parasite populations would appear in those selected fields than might be found generally around the liberation point.

FIELD AND LABORATORY TECHNIQUE

For phases of investigation on the field status of corn borer parasites in which samples of the host were needed, collections were made at the time of year when equilibrium between parasites and host had been reached. For observations on parasitization in borers of the overwintering generation, collections were made in the fall after the active parasite season and when the host larvae had attained full growth. Feeding in the laboratory and lessened mortality during winter storage were thereby avoided. Owing to the earlier seasonal maturity of borers in the Lake States, collections were begun in that area about October 1, 2 weeks earlier than the initial date in the East. In both areas it was planned to complete field observations before adverse weather decreased the efficiency of operations.

The survey to determine the extent of parasitization in first-generation borers in the Eastern States area was made just prior to the appearance of numbers of second-generation borers. Thus, owing to variations in the rate of individual development, mature larvae, pupae, and pupal exuviae appeared in such collections, whereas in fall collections the host stage consisted entirely of mature larvae. The objective was to obtain as nearly as possible the number of hosts of a given generation that were killed by parasites, so that if and when it became possible to determine the mortality that would have resulted from other factors, an exact evaluation of the mortality caused by parasites might be obtained.

The technique of borer collection was gradually improved and in 1941 the following method was used. A salve tin, about 2 inches in diameter and 1¼ inches deep, was fastened with elastic bands to a tight-fitting superstructure having a funnel-shaped opening in the top. The salve tin contained a roll of corrugated cardboard 13 inches long by 1 inch wide. This cardboard supplied sufficient cells in the corrugations for 50 borers, without crowding. Borers taken from standing, shocked, or stubblefields of sweet and field corn, or from weeds and debris, were dropped into the container and soon crawled into concealment in the corrugations (fig. 12). When 50 borers had been taken, the salve tin was removed from the superstructure, covered, and placed in a mailing tube with a record form giving full data on the collection.

Included in the borer sample were all ectoparasites and all cocoons and puparia of endoparasites that had issued[11] prior to

[11] The term "emerge" refers to the appearance of adults in the natural process of metamorphosis. The term "issue" refers to the process by which endoparasitic species leave the host.

collection but had caused the death of borers of the generation being sampled. Host remains and the parasite (or cluster of parasites of gregarious or polyembryonic species) responsible for its death were placed in a No. 0 gelatin capsule. When received at the laboratory the cans were held at a low temperature to prevent overactivity of the borers until they could be segregated, which was usually done on the day following receipt but could be delayed by storing the cans in a cool place.

Isolation is essential to prevent cannibalism and reduce the chances for epidemics of entomogenous diseases. Shell vials measuring 50 by 17 mm. were used for segregating the larvae. Each vial was covered with a cap formed from a 1-inch circle of 40-mesh screen wire. Each contained a piece of white blotting paper (1¼

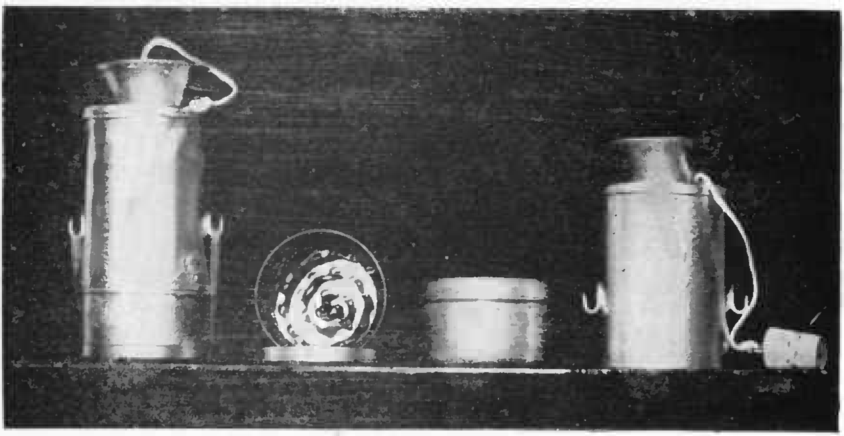

FIGURE 12.—Containers used in collecting European corn borer larvae.

inches by ⅜ inch), to absorb excess water and retain moisture. Vials were carried in shallow trays equipped with cross pieces for elevating the cap end of the vial, thus facilitating the moistening process and the examination of the contents. Two hundred vials, or material from two samples, were put in each tray (fig. 13).

Immediately after isolation of the vials, moisture was applied by means of a fine jet of water forced through the screen caps. The trays were then racked in a refrigerator room (fig. 14) held at a temperature of 34°–36° F., and were kept there until the diapause requirements of the host larvae had been satisfied, or for about 3 months. Decreasing this hibernation interval to any great extent, especially when dealing with the single-generation strain of the borer, causes excessive mortality of the host larvae. Usually about March 1 the refrigerating unit was shut off and the larvae were allowed to warm slowly before being placed in an environment favoring their development. This environment consisted of a chamber held at 80° by a thermostat regulating a small fan-type electric heater and at a relative humidity of 70

FIGURE 13.—Tray for holding isolation vials in inclined position to facilitate observation and handling of European corn borer larvae and the application of contact moisture.

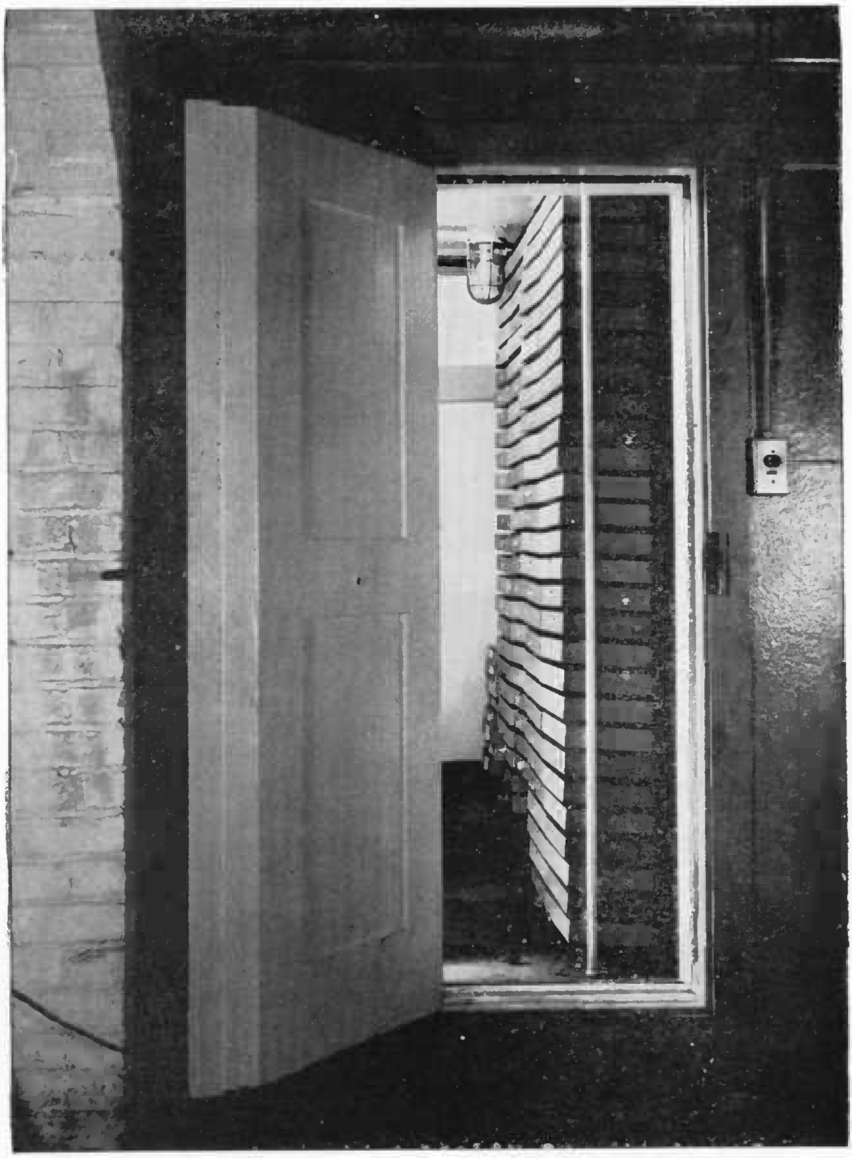

FIGURE 14.—Refrigeration room used for storage of European corn borer hibernating material, Toledo, Ohio.

percent or above, controlled by a hygrostat regulating a humidifying unit similar to that described by Bradley and Berndt.[12]

The trays were stacked in mobile racks holding from 57 to 108 trays. At the Moorestown, N. J., corn borer laboratory wooden

[12] BRADLEY, W. G., and BERNDT, O. E. AN INEXPENSIVE HUMIDIFIER FEATURING HYGIENIC PRINCIPLES. U. S. Bur. Ent. and Plant Quar. ET-96, 2 pp., illus. 1937. [Processed.]

racks were used and the trays were slid in and rested on angle irons fastened to the uprights (fig. 4). At Toledo, Ohio, the racks were constructed of sections of ½-inch iron pipe welded together. The trays were supported at front and back on ¼-inch iron rods, the ends of which were set into holes drilled at proper intervals in the pipe frame (fig. 15).

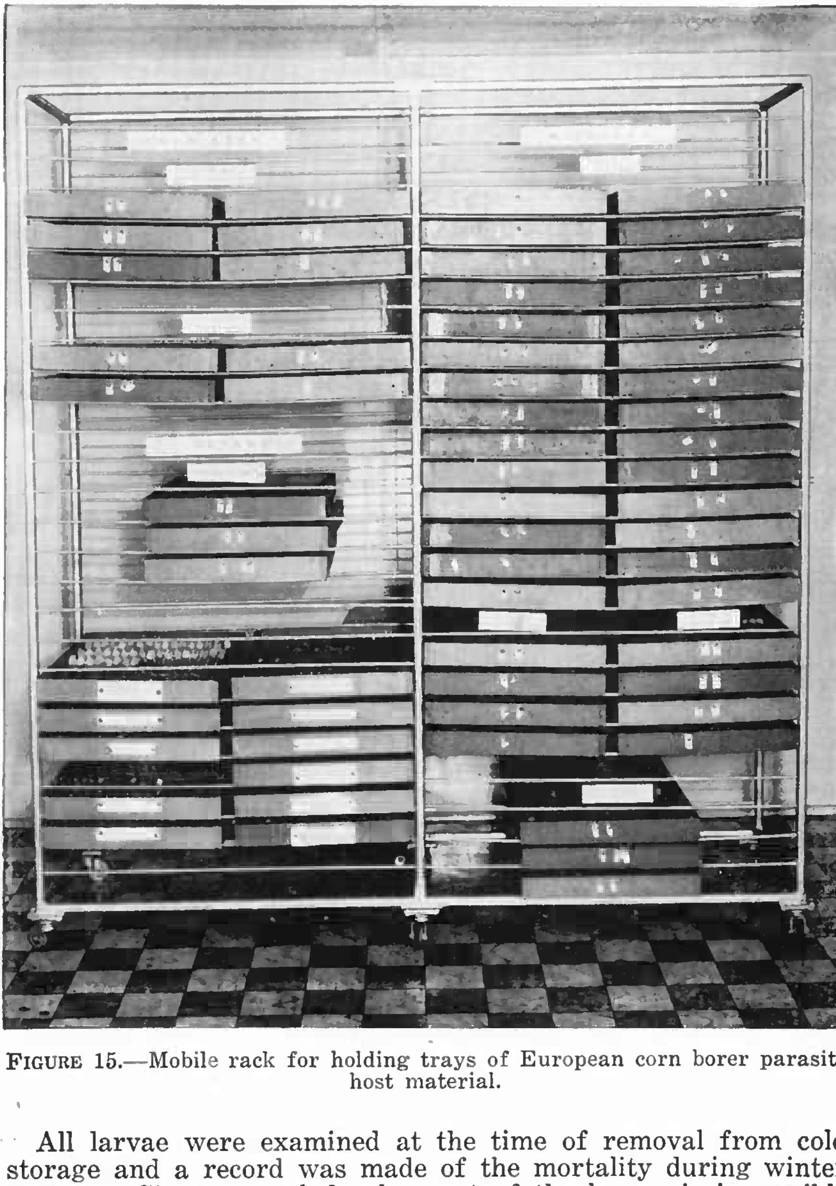

FIGURE 15.—Mobile rack for holding trays of European corn borer parasite host material.

All larvae were examined at the time of removal from cold storage and a record was made of the mortality during winter storage. Since normal development of the larvae is impossible without contact moisture, water was applied at the time of removal and once each week during the developmental period.

Material of this type may be attacked in the laboratory by the fungus *Beauveria bassiana,* which at times causes considerable mortality. Various methods of combating this disease in stored and experimental material in the laboratory were tested. The tests included the application of germicidal solutions to the living material or the containers, and also included germicidal irradiation. The fungicide found most desirable was basic phenylmercuric nitrate (0.067 percent in aqueous solution), dissolved in the contact-moisture water at the rate of 15 cc. of the solution to 1 quart of water.

The entire lot of material was examined weekly or semiweekly and all parasites that issued were noted. Vials containing freshly formed cocoons and puparia were removed from the trays and put in emergence racks similar to those described by Painter.[13]

The time elapsing from cold storage to emergence of adult parasites, and also the emergence trend or curve for each exotic parasite under controlled environmental conditions, could easily be charted. Such information is often useful in recolonization work.

Since all material was isolated, each adult parasite and the remains of its immature stages could readily be associated with the remains of its host.

Development of the parasite survey material was allowed to continue for a number of days, until practically all emergence was completed. Since it was found that all parasite emergence is completed a considerable time before all the host insects have emerged, observations were concluded within a week after the maximum interval of parasite emergence, as determined by past records. All vials were closely packed in wire racks holding about 200 each. The open ends of the vials were faced in one direction to facilitate removal of undissolved material by spraying after the vials had been thoroughly boiled in a solution of washing powder and lye. The vials were dipped in a weak aqueous solution of hydrochloric acid, to neutralize the alkali and prevent deposit after boiling, and were then thoroughly rinsed.

Before beginning collection each year, the entire list of material to be used on the work was assembled. Each of the thousands of vials received its small piece of blotting paper, and the small collecting cans were fitted with their corrugated-paper strips. All material, including blank note forms, superstructures, and vial trays, were placed in a fumigation chamber and treated with a fungicide consisting of formaldehyde fumes generated by uniting 10 ounces of potassium permanganate with 500 cc. of 40-percent formalin for each 1,000 cubic feet of space. The cold-storage room and the incubator room were painted with white high-gloss paint each year just before receiving the parasite material.

FIELD RELEASES

Since the inception of the project on biological control of the European corn borer, 21 species of parasites have been intro-

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[13] PAINTER, H. R. REARING BOX FOR SMALL INSECTS. U. S. Bur. Ent. and Plant Quar. ET-40, 1 p., illus. [Processed.]

duced from Europe and the Orient and released in the United States, as shown in the following tabulation:

Parasites	*Imported from*
Diptera:	
Aplomya mitis (Meig.)	Europe
Lydella stabulans grisescens R. D.[1]	Europe, the Orient
Nemorilla floralis (Fall.)	The Orient
Pseudoperichaeta erecta (Coq.)	The Orient
Pseudoperichaeta roseanae (B. & B.)	Europe
Hymenoptera:	
Apanteles sp.	The Orient
Apanteles thompsoni Lyle	Europe, the Orient
Bracon atricornis (Smith)	Europe, the Orient
Campoplex multicinctus Grav.	Europe
Campoplex pyraustae Smith	Europe
Chelonus annulipes Wesm.[1]	Europe
Zaleptopygus flavo-orbitalis (Cameron)[1]	The Orient
Campoplex alkae (Ell. & Sacht.)	Europe, the Orient
Eulophus viridulus Thoms.[1]	Europe
Exeristes roborator (F.)	Europe
Horogenes punctorius (Roman)[1]	Europe, the Orient
Macrocentrus gifuensis Ashm.[1]	Europe, the Orient
Meteorus nigricollis (Thoms.)	Europe
Microbracon brevicornis Wesm.	Europe
Microgaster tibialis Nees.	Europe, the Orient
Phaeogenes nigridens Wesm.[1]	Europe, the Orient

[1] Species on a maintenance basis.

Of this number, 7 are considered as being on a maintenance basis at one or more points, as determined from information obtained in all surveys made through 1940. Of the remaining 14 species, some have shown initial establishment following current releases, whereas others have never been recovered.

The discussions which follow give the essential information on all parasites introduced prior to January 1, 1941.

IMPORTED PARASITES IN A MAINTENANCE STATUS IN THE UNITED STATES

LYDELLA STABULANS GRISESCENS R. D. (Fig. 16)

Order: Diptera.

Family: Larvaevoridae.

Imported from: Europe and the Orient.

Preferred host stage: Fourth-instar larva.

Method of parasitization: Ovoviviparous; deposits living larva in frass at entrance to borer tunnel.

Hibernation: Second-instar lava within mature borer; rarely as a first-instar larva.

Considerable confusion has existed as to the systematic identity of this and a closely related species indigenous to the United States. For a number of years the two were considered as morphologically identical and, following the importation of the European species, references to the native parasite on several stem-boring lepidopterous larvae were noted under the name *Masicera senilis* Meig.

Thus, *Masicera senilis* is listed by Decker (*12*) as parasitic on the stalk borer (*Papaipema nebris* (Guen.)) and *Luperina stipata*

(Morr.), by Breakey (*9*) on *Macronoctus onusta* Grote, and by Lowry (*22*) on *Papaipema nebris* (Guen.). An exhaustive study by E. W. Beck revealed that the claws on the hind tarsi of the male showed valid diagnostic characters. Attention was called to this character by Villeneuve[14] soon after the first importation of the foreign species. He pointed out that the claws on the hind tarsi of the male were longer and more slender in the species autochthonous to the United States and the species he called

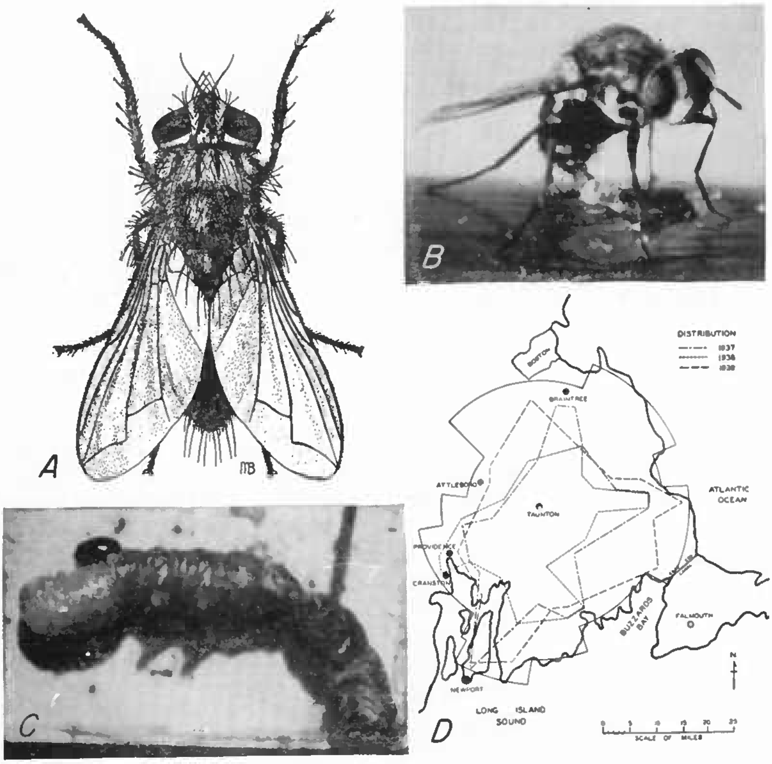

FIGURE 16.—*Lydella stabulans grisescens: A*, Adult female, × 9; *B*, female larvipositing in frass at entrance to European corn borer tunnel, × 9; *C*, third-instar larva emerging from rupture in ventral side of thorax of host (European corn borer), × 6; *D*, distribution in the vicinity of Taunton, Mass. Surveyed area is indicated by solid line.

Lydella nigrita. This differentiation was apparently overlooked in later determinations, for it is *L. nigrita* to which Decker et al. have reference, and not the exotic species, *Lydella stabulans grisescens,* formerly called *Masicera senilis.* A short description of the species and a brief account of its biology and seasonal history in Europe have been published by Thompson and Thompson (*37*). Further knowledge of its habits and biology has been obtained from studies made in the United States for the purpose of perfecting handling and colonization technique.

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[14] Villeneuve, George. Personal communication to H. L. Parker, August 17, 1931.

BIOLOGY

Longevity of Adults

A study was made of 4 groups, each consisting of about 20 male and 20 female adults. These groups were considered similar in every respect, having emerged on the same date, and mated at the same time, and were handled in the same manner at a temperature of 80° F. and 70 percent relative humidity. The only apparent variation of the groups was the food supplied the different groups. This consisted of water, honey, sugar solution, and granulated sugar. All groups were supplied with water, which was replenished daily.

Food was evidently a necessity, because the flies soon died when given water only. Sugar solution proved to be the best food, but there was very little difference in the food value of sugar solution and dry sugar. The average number of days the adults lived when fed the four different foods was as follows: Water only, 5.6; honey, 10.5; sugar solution, 16.9; and granulated sugar, 14.0. The life of the males was from 1 to 7 days shorter than that of the females.

Longevity of Females Given an Opportunity to Larviposit

Females (fig. 16, *A*) given an opportunity to larviposit did not live longer than those prevented from doing so. Food supply was not considered so important in this case, as the females feed considerably on the juices of the host plants, and this undoubtedly would be reflected in the length of life. The average length of life of 10 virgin females fed granulated sugar was 13 days.

Coition

Females were observed to copulate within a short time after emergence, even before the wings were completely spread. The males apparently are not sexually mature at the time of emergence, as newly emerged males never copulated, but 1 or 2 days after emergence they copulated freely. Rarely was a female observed to mate the second time. No courtship takes place. The male approaches the female and copulation occurs without hesitation. The male has been observed to settle upon the female directly from flight. Dissection disclosed that one mating of even less than average time spent in coition was ample to insure excellent fertility.

Mating has been accomplished at temperatures ranging from 68° to 85° F., with the optimum approaching 80°. When the higher temperatures prevailed (about 85°), the adults became very active, and this activity tended to prevent mating. It was controlled by supplying moisture and air circulation by means of an electric fan, which had a very marked cooling effect and induced mating. The current of air caused the females to cling to the resting surface, and if properly regulated often brought about coition when other methods failed. Light of daylight in-

tensity was essential for copulation. Temporary darkening of the mating cage was often followed by intense sexual activity.

The data at hand showed no apparent correlation between the temperature and the time spent in copulation. The latter ranged from 5 to 66 minutes, averaging approximately 25 minutes.

Fecundity

The greatest number of eggs observed in the uterus of a female was approximately 1,000. This number is at least one-third higher than the average number of eggs per female. The number of eggs in the uterus was observed to vary directly with the size of the female. For example, 4 mated females of different sizes were selected, incubated 11 days, and dissected. The largest female contained 470 eggs, the next largest 400, the third 240, and the smallest 180 eggs. These females were all permitted to mate undisturbed until coition ceased naturally. The percentage of larvae or fertile eggs was practically the same in each group—85, 90, 95, and 90 percent, respectively.

The length of time spent in coition varied greatly. To check the effect of this variation on the fecundity of females, an experiment was conducted, the results of which are shown in table 14.

TABLE 14.—*Effect of variation in length of coition period on reproduction of Lydella stabulans grisescens*

Females	Coition period	Eggs laid	Resulting larvae	
Number	*Minutes*	*Number*	*Number*	*Percent*
2	1.5	30	0	0
1	1 to 2.5	80	0	0
8	4	1,655	139	8.4
2	5	600	309	51.5
9	6	3,435	1,701	49.5
6	8	1,480	996	67.3
6	15–66	2,800	2,341	83.6

The females were held under controlled conditions of 80° F. and 70 percent relative humidity, and were dissected at the end of 10 to 11 days. The table shows an increase in the number of eggs and larvae per female as the duration of coition increased, indicating that this factor influences the number of eggs that pass from the ovaries into the uterus and also the percentage of fertility. Probably because of individual variation, the data do not show proportionate perfect correlation between the number of minutes spent in coition and the number of offspring.

Gestation

The reproductive system of the female is similar to that of most of the larvaevorid parasites that retain the eggs until they are incubated. It consists of two ovaries, the oviducts of which unite to form the uterus. At the junction of the uterus and the ovi-

ducts are two accessory glands and three amber-colored pear-shaped bodies, the spermathecae, which are joined to the uterus by slender tubules. In a virgin female the uterus is small and very short, and is covered with a mass of tracheal tubes. After the females have mated, the uterus becomes filled with eggs and is many times its original size. In females having an average length of life, the ovaries become shriveled and almost disappear. The eggs are retained in the uterus until they have incubated. The larva is active within the egg and can be seen moving its mandibles.

The ovaries are of the meroistic type, and consist of 39 to 59 ovarioles per ovary. The eggs pass into the uterus and are packed in one layer, each parallel to the longitudinal axis of the others with the anterior ends of each to the same side. When filled to capacity, the uterus is curved into a half-moon shape.

Lydella stabulans grisescens has never been observed to reproduce parthenogenetically. Only rarely were large numbers of eggs found in the uterus of virgin females, although it was common to find from 10 to 25 eggs, all infertile. Soon after the females mated, the eggs began to pass from the ovaries to the uterus and this continued for several days. Many mated females were dissected and the uterus was found to be filled with infertile eggs.

Larviposition

A *Lydella stabulans grisescens* female larviposits either directly into the host's burrow at the opening or in the frass and excrement that cover an opening. Occasionally, the larvae are deposited upon the stalks a short distance from the burrow, or, more frequently, in frass which does not cover a host tunnel. Females that have been given an opportunity to larviposit but have passed the incubation period, will larviposit upon tiny pieces of frass, and will continue to larviposit at the same spot after the frass has been removed. The urge to larviposit is so great that little stimulus is necessary to cause the females to scatter their larvae promiscuously.

A female, when larvipositing, stands over the opening to the host's burrow and bends her abdomen under until the ovipositor is pointing downward and slightly forward, (fig. 16, *B*). The tiny larvae are forced out of the vent onto the surface or are brushed off with a quick downward and backward movement of the tip of the abdomen as the female regains her normal position.

The females apparently are attracted to a corn borer burrow by the odor given off from the excrement and possibly from the host itself. The female runs hurriedly along a stalk and appears to be searching from side to side. Often when she comes upon frass she feeds a moment before larvipositing.

In a laboratory test of real frass and burrows, in comparison with artificial frass and openings as stimuli inducing deposition, the parasites larviposited four times as often at a burrow containing a borer as at an artificial burrow covered with borer frass and excrement, and there was no deposition at artificial openings. Dried frass is equally as attractive as fresh, moist frass.

In a second experiment three pieces of uninfested stalk, each having an artificial burrow, were utilized. One burrow was partially covered with corn borer frass, another with artificial frass, and a third was left untreated. During a 30-minute observation period, 25 females larviposited 54 times in the real frass, 14 times in the manufactured frass, and 12 times at the uncovered hole. This fact indicated that the borer frass stimulated the females to larviposit, but the stimulus was not strong enough to attract the entire group to the one stalk. Odor is apparently the strongest stimulus, but another tropism must have enabled the females to find the other two openings. Care was exercised in making the artificial "burrows" to prevent any corn borer odor from emanating from the stalks.

One borer left its burrow and wandered about the cage, leaving a trail. Four depositions were observed upon the trail, and two females larviposited directly upon the borer. This deposition was believed to be accidental, however, as the females continued to larviposit in the frass and at the burrow from which the borer had crawled.

In slightly over 1 hour, 15 females larviposited 191 times at 3 burrows, a fact which indicated that they were not selective, for each female larviposited many times at the same burrow. The average number of depositions per female was 12.7.

From 1 to 4 larvae were deposited at one time, with an average of less than 2. A total of 57 depositions were observed and the eggs and larvae in each were recorded. Seventy-seven larvae and 45 infertile or undeveloped eggs were deposited, with an average of 2.1 eggs and larvae per deposition.

Mated females held in an environment of 80° F. and 70 percent relative humidity deposited the first larvae on the fifth day after mating, and also deposited infertile eggs and a few undeveloped ones. Normally, *Lydella stabulans grisescens* deposits the larvae and the empty eggshells at the same time.

Hatching does not take place in the uterus, but during the act of larviposition. Rarely did an egg hatch after deposition, for usually these eggs are infertile or contain dead or very weak larvae. The larvae or eggs are deposited indiscriminately in the order in which they occur in the larval sac. The eggs nearest the genital opening develop first, and unless an opportunity is given for larviposition the eggs are retained in the uterus. When this happens, hatching sometimes takes place within the uterus, and the larvae work their way either out of the genital opening or through the body of the mother, eventually causing her death. Larvae have been observed in the eyes of a dead female which, a few hours before, had been active and apparently normal.

Parasite and Host Relationship

All instars of *Pyrausta nubilalis*, excepting the first, were successfully parasitized by *Lydella stabulans grisescens* in the laboratory. The mortality due to parasitization of the smaller larvae apparently was not higher than in the last two instars. The size of the puparia depended on the size of the host, the largest borers producing the largest puparia. The fourth-instar borers had

the highest percentage of parasitization and were judged to be the most suitable hosts for parasitization.

In a study utilizing various sizes of borers, only 24 percent of those in the second and third instars were successfully parasitized, whereas approximately 54 percent of fourth- and fifth-instar borers produced parasites.

Larval Habits and Development

The larva of the internal parasite *Lydella stabulans grisescens* passes through three instars, but is sessile only in the second. The first-instar larva exists from one to several hours as a free-crawling individual seeking its host. The third-stage larva becomes unattached as soon as its host dies. It makes contact directly with the air for oxygen and, to a certain extent, depends on locomotion to obtain food within the host remains.

When larvae are permitted to develop at a constant temperature of 80° F. and 70 percent relative humidity, the first-instar period averages 3.12 days in length, the second 2.19 days, and the third 2.72 days, or a total of 8.03 days.

Under normal conditions the first-instar larva is deposited upon the corn plant, near a burrow opening, in frass thrown out by the host. It immediately enters the burrow and seeks its host. A burrow in a green plant is very moist, a condition vital to the success of the larva in finding its host. In the laboratory larvae in dry stalks soon become entangled in dust and small particles of frass, which cling to the moist skin. They become sluggish and apparently exhausted with efforts to free themselves. However, if moisture is applied the larvae continue to crawl about for several hours and have been kept alive in green stalks 36 hours. Contact moisture is therefore beneficial to the larva from the time it is deposited until it reaches its host and is able to enter.

The parasite larva has been observed to enter the host through a spiracle, the integument between segments, and the anus. The mouth parts are well adapted for cutting through the chitin, having a sawtooth edge and being very sharp. The activity of the larva entering its host often causes the host to squirm or wriggle and bite the area the larva is attacking. At times, the host larva dislodges the parasite or injures it so that it fails to gain entrance.

After entering the host, the larva works its way to one of the main tracheal trunks, which it punctures, apparently by cutting with the mandibles. It then forces the posterior end containing the stigmata into the opening, and remains in this position until the host is practically grown. The irritation caused by the larva induces an excessive proliferation of the tracheal epithelium cells, which form a sheath about the parasite. This sheath is heavily sclerotized for about one-third of its length at the base. The sclerotized part is dark and opaque, whereas the remainder is translucent to transparent. Occasionally, the sheath completely envelops the larva, especially in a hibernating or diapause host. Practically all the larvae are attached in the anterior half of the host.

During the first and second instars the larvae feed almost entirely on the body fluids of the host and do not injure the fatty

lobes and internal organs. The third-instar larvae feed on the fatty tissue and, just before issuing, consume most of the internal organs. Immediately upon the death of the host, the parasite leaves the sheath and forces an opening in the skin of the host. In most of the observations the opening was made ventrally through the first thoracic segments. The larva continues to feed and obtains oxygen directly from the air by forcing its anal stigmata out of the opening.

When it has finished feeding, the larva leaves the host remains through the rupture in the skin (fig. 16, *C*) and forms a puparium in contact with the host skin or in its immediate vicinity.

For 92 individuals reared in an incubator chamber maintained at 80° F. and 70 percent relative humidity, the period from time of parasitization to emergence of the adults averaged 15.85 days. That of 43 males averaged 14.86 days and that of 49 females 16.71 days. The males emerged first and mating did not usually take place until the second and third days. The females apparently were ready to mate immediately upon emergence but the males required a period of about 2 days to become sexually mature. The difference in the life cycle of the sexes holds true in both the larval and pupal stages as follows: Larval stage, males 7.02 days, females 8.08 days; pupa, males 7.83 days, females 8.63 days. In small lots the numbers of males and females are practically equal.

SEASONAL HISTORY

Studies on the seasonal history of *Lydella stabulans grisescens* were conducted during the years 1930 and 1931. Borers were collected in the spring before insect activity began, and collection was continued throughout the year at regular intervals until all activity had ceased in the fall. These borers were carefully dissected in the laboratory and observations were made as to the trend of the parasite's larval development. In conjunction with these studies a series of cage experiments was conducted and the information thus obtained was used to interpret the significance of the more generalized field observations.

Cages 10 by 6 by 6 feet (fig. 17), utilized in the seasonal history studies, were placed over corn artificially infested with European corn borer larvae. The parasites were then liberated in the first of a series of two cages and observations on the first generation were made. All adults that emerged in the first-generation cages were transferred to the second cage and observations were repeated for the second generation. These observations, including dissection of corn borer larvae taken from the two cages, were then compared with records of observations made in the field.

Although no full account of these cage experiments is given in this paper, the data obtained in this manner were of great value in interpreting field observations and they supplied information supplementing field observations materially. Data on emergence were augmented by records from large screened cages located at Monroe, Mich., and at Bono and Sandusky, Ohio.

Lydella stabulans grisescens hibernates in the larval stage inside the host, usually in the second instar, although a few remain

in the first instar. During the hibernation period they are attached to a main tracheal trunk of the host, as illustrated by Thompson and Thompson (*37*), and are nearly or completely enclosed by a sheath which is a growth from the tracheal epithelium of the host. During this period the parasite feeds only on the blood in the body cavity and the host does not appear to suffer any harm. The parasitized larvae are indistinguishable from the unparasitized ones unless the heavily sclerotized and blackened portion of the tracheal sheath is visible as a black spot through the skin of the host.

Lydella stabulans grisescens has two generations annually, the adults of the second generation emerging in the spring of the following season. The overwintered larvae do not develop beyond the second instar until the following spring. The diapause tendency is not restricted to the second generation, for a small percentage of the first generation enter diapause in the first and second instars, and overwinter in a manner similar to those of the second generation. Spring development begins early in April and the third-instar larvae are in evidence by the middle of the month. The appearance of third-instar larvae within the host is followed by first issuance of the parasite about May 15 and subsequent first-adult emergence the last of May.

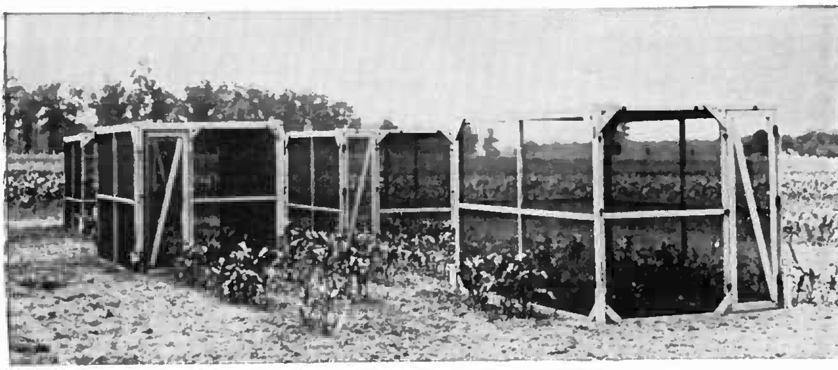

FIGURE 17.—Large outdoor cages for biology studies of European corn borer parasites.

COLONIZATION

Material for colonization of this species has been imported from both Europe and the Orient. This tachinid fly was among the first parasites of the corn borer to be imported, a small colony of 70 adults having been released at Watertown, Mass., in 1920. Since then it has been more widely colonized than any other of the introduced parasites. As shown in table 15, all the earlier colonies were located in New England, and a considerable number of the earliest, consisting of European stock, in northeastern Massachusetts. By 1930 parasitization in this locality had increased to the point where it was feasible to collect for further distribution. During the 7-year period 1930–37 over 14,000 adults were taken from eastern Massachusetts for colonization elsewhere.

TABLE 15.—*Numbers of Lydella stabulans grisescens adults released in the United States, 1920–40*

State and County	Township	Origin[1]	1927	1928	1929	1930	1931	1932	1933	1934	1935	Total[2]
Connecticut:[3]												
Fairfield	Fairfield	D	0	0	0	0	0	0	0	0	0	1,987
Hartford	E. Hartford	E	0	0	0	0	0	0	0	2,454	0	2,454
Do	do	O	0	0	0	0	0	0	0	6,105	0	6,105
Middlesex	Haddam	E	0	0	0	0	0	0	0	0	1,823	1,823
New Haven	Milford	E	0	0	0	0	0	0	0	2,379	0	2,379
New London	E. Lyme	E	0	807	725	8,455	4,185	11,017	0	0	0	25,189
Do	do	O	0	0	111	1,424	23	1,226	0	0	0	2,784
Do	do	D	0	0	0	0	2	0	0	0	0	2
Total			0	807	836	9,879	4,210	12,243	0	10,938	1,823	42,723
Indiana:												
Adams	Union	E	0	0	0	0	0	0	0	0	3,974	3,974
Allen	Jackson	E	0	0	0	2,078	0	0	0	0	0	2,078
Do	Lafayette	E	0	0	0	2,068	0	0	0	0	0	2,068
De Kalb	Butler	E	0	0	0	1,982	0	0	0	0	0	1,982
Huntington	Clear Creek	E	0	0	0	0	0	0	0	0	3,966	3,966
Lagrange	Bloomfield	E	0	0	0	2,081	0	0	0	0	0	2,081
Noble	Washington	E	0	0	0	2,086	0	0	0	0	0	2,086
Steuben	York	E	0	0	722	0	0	0	0	0	0	722
Do	do	O	0	0	2,414	0	0	0	0	0	0	2,414
Whitley	Union	E	0	0	0	0	0	0	0	0	3,964	3,964
Total			0	0	3,136	10,295	0	0	0	0	11,904	25,335
Maine: York	Wells	E	0	0	0	0	0	0	0	0	1,927	1,927
Maryland:[4] Worcester	Newark	D	0	0	0	0	0	0	0	0	0	5,365
Massachusetts:[5]												
Barnstable	Falmouth	E	0	1,024	237	8,877	6,414	0	0	0	0	16,552
Do	do	O	0	0	155	667	0	0	0	0	0	822

Do	do	D		0	0	0	62	390	0	0	0	0	452
Bristol	Dighton	O		0	0	15	0	0	0	0	0	0	15
Do	Swansea	E		0	1,977	720	0	0	13,331	0	0	0	16,028
Do	do	O		0	0	163	0	0	228	0	0	0	391
Do	do	D		0	0	0	0	0	293	0	0	0	293
Essex	Peabody	E		0	0	0	0	0	824	0	0	0	824
Do	do	O		0	0	0	0	0	106	0	0	0	106
Do	Saugus	E		553	0	34	89	3,613	0	0	0	0	5,323
Do	do	O		0	0	34	7	803	0	0	0	0	844
Do	do	D		0	0	0	3	56	0	0	0	0	59
Franklin	Bernardston	E		0	0	0	0	0	0	0	0	1,906	1,906
Hampden	Agawam	E		0	0	0	0	0	0	0	0	1,984	1,984
Hampshire	Hadley	E		0	0	0	0	0	0	0	0	1,949	1,949
Middlesex	Arlington	E		1,556	1,074	0	395	0	0	0	0	0	3,197
Do	do	O		0	0	45	0	0	0	0	0	0	45
Do	do	D		0	0	0	5	0	0	0	0	0	5
Do	Concord	E		0	0	0	0	0	10,114	0	0	0	10,114
Do	do	D		0	0	0	0	0	41	0	1,411	0	1,452
Do	Malden	E		524	0	0	0	0	0	0	0	0	886
Do	Medford	E		637	0	0	0	0	0	0	0	0	2,365
Do	Watertown	E		0	0	0	0	0	0	0	0	0	70
Norfolk	Quincy	E		6,150	2,578	0	0	0	0	0	0	0	8,728
Plymouth	Bridgewater	O		0	0	0	0	10,199	3,209	0	0	0	13,403
Suffolk	Revere	E		372	0	0	0	0	0	0	0	0	655
Worcester	Charlton	E		0	0	0	0	0	0	0	0	1,985	1,985
Do	Lancaster	E		0	0	0	0	0	0	0	1,629	0	1,629
Total				9,792	6,653	1,403	10,105	21,475	28,146	0	3,040	7,824	92,087
Michigan:													
Branch	Butler	E		0	0	0	2,055	0	0	0	0	0	2,055
Genesee	Genesee	E		0	0	0	2,599	0	0	0	0	0	2,599
Hillsdale	Somerset	E		0	0	0	1,168	0	0	0	0	0	1,168
Huron	Sebewaing	E		0	0	0	0	0	0	0	0	1,995	1,995
Jackson	Henrietta	E		0	0	0	2,031	0	0	0	0	0	2,031
Lapeer	Goodland	E		0	0	0	0	0	0	0	0	1,992	1,992
Lenawee	Fairfield	O		0	0	0	2,101	1,865	0	0	0	0	3,966
Do	Tecumseh	E		0	0	0	2,053	2,968	0	0	0	0	5,021
Livingston	Conway	E		0	0	0	2,006	0	0	0	0	0	2,006
Macomb	Chesterfield	E		0	0	0	2,305	0	0	0	0	0	2,305

TABLE 15.—*Numbers of Lydella stabulans grisescens adults released in the United States, 1920–40—Continued*

State and County	Township	Origin[1]	1927	1928	1929	1930	1931	1932	1933	1934	1935	Total[2]
Michigan—Cont'd.:												
Macomb	Harrison	E	0	0	0	0	4,872	0	0	0	0	4,872
Monroe	Erie	E	318	4	0	0	0	28,675	0	0	0	28,997
Do	Monroe	E	0	2,285	469	0	4,340	2,063	0	0	0	9,157
Do	do	O	0	0	859	0	0	0	0	0	0	859
Oakland	Highland	E	0	0	0	2,371	0	0	0	0	0	2,371
Do	Oxford	E	0	0	0	3,709	8,841	2,085	0	0	0	14,635
Do	Southfield	E	0	0	0	1,965	2,382	0	0	0	0	4,347
St. Clair	Columbus	E	0	802	184	2,351	4,943	2,084	0	0	0	10,364
Do	do	O	0	0	3,570	0	0	0	0	0	0	3,570
Sanilac	Lexington	E	0	0	0	0	0	0	0	0	1,993	1,993
Tuscola	Koylton	E	0	0	0	0	0	0	0	1,796	0	1,796
Washtenaw	Augusta	E	0	0	0	7,642	0	0	0	0	0	7,642
Do	Northfield	E	0	0	0	3,485	0	0	0	0	0	3,485
Wayne	Livonia	E	0	0	0	0	0	0	0	1,993	0	1,993
Total			318	3,091	5,082	37,841	30,211	34,907	0	3,789	5,980	121,219
New Hampshire:												
Hillsboro	Hollis	E	0	0	0	0	0	0	0	0	1,782	1,782
Rockingham	Raymond	E	0	0	0	0	0	0	0	0	1,883	1,883
Strafford	Strafford	E	0	0	0	0	0	0	0	0	1,904	1,904
Total			0	0	0	0	0	0	0	0	5,569	5,569
New Jersey:[6]												
Atlantic	Egg Harbor	E	0	0	0	0	0	0	0	0	1,997	1,997
Burlington	Burlington	D	0	0	0	0	0	0	0	0	0	120
Do	Woodland	E	0	0	0	0	0	0	0	0	508	508
Do	do	D	0	0	0	0	0	0	0	0	0	1,080
Monmouth	Atlantic	E	0	0	0	0	0	0	0	0	1,980	1,980
Ocean	Brick	E	0	0	0	0	0	0	0	0	1,976	1,976
Total			0	0	0	0	0	0	0	0	6,461	7,661

New York:													
Albany	Berne	E		0	0	0	0	0	0	0	0	1,983	1,983
Cattaraugus	Franklinville	E		0	0	0	2,100	0	0	0	0	0	2,100
Do	Indian Reservation	E		0	1,270	1,669	0	0	0	0	0	0	2,939
Do	do	O		0	0	2,506	0	0	0	0	0	0	2,506
Do	Randolph	E		0	0	0	3,250	0	0	0	0	0	3,250
Cayuga	Throop	E		0	0	0	0	0	2,071	0	0	0	2,071
Chautauqua	Portland	E		0	149	0	2,061	0	0	0	0	0	2,210
Do	Westfield	E		0	1,713	0	0	0	0	0	0	0	1,713
Erie	Lancaster	E		0	795	177	0	0	0	0	0	0	972
Do	do	O		0	0	304	0	0	0	0	0	0	304
Fulton	Mayfield	E		0	0	0	0	0	0	0	0	3,913	3,913
Genesee	Batavia	E		0	0	0	2,072	0	0	0	0	0	2,072
Do	Stafford	E		0	0	0	2,099	0	0	0	0	0	2,099
Jefferson	Adams	E		0	0	0	2,098	4,800	2,082	0	0	0	8,980
Do	Clayton	E		0	0	0	2,081	3,282	0	0	0	0	5,363
Monroe	Hamlin	E		0	0	0	2,092	0	0	0	0	0	2,092
Montgomery	Palatine	E		0	0	0	0	0	0	0	0	3,901	3,901
Niagara	Porter	E		0	0	0	2,097	0	0	0	0	0	2,097
Onondaga	Clay	E		0	0	0	0	0	2,065	0	0	0	2,065
Ontario	Phelps	E		0	0	0	0	0	2,084	0	0	0	2,084
Orleans	Yates	E		0	0	0	2,094	0	0	0	0	0	2,094
Oswego	Scriba	E		0	0	0	2,075	3,59	0	0	0	0	5,671
Schenectady	Glenville	E		0	0	459	16,370	0	0	0	0	0	16,829
Do	do	O		0	0	247	2,080	0	0	0	0	0	2,327
Schoharie	Jefferson	E		0	0	0	0	0	0	0	0	1,970	1,970
Suffolk	Southhold	E		0	0	0	0	0	5,916	19,365	0	0	25,281
Do	do	O		0	0	0	0	0	0	278	0	0	278
Do	do	D		0	0	0	0	0	0	159	0	0	159
Wayne	Ontario	E		0	0	0	0	7,154	0	0	0	0	7,154
Do	Wolcott	E		0	0	0	0	3,586	0	0	0	0	3,586
Wyoming	Java	E		0	0	0	2,090	0	0	0	0	0	2,090
Total				0	3,927	5,362	44,659	22,418	14,218	19,802	0	11,767	122,153
Ohio:													
Ashland	Ruggles	E		0	0	0	2,089	0	0	0	0	0	2,089
Ashtabula	Saybrook	E		0	0	0	2,053	0	0	0	0	0	2,053
Auglaize	Washington	E		0	0	0	0	0	0	0	2,097	0	2,097

TABLE 15.—*Numbers of Lydella stabulans grisescens adults released in the United States, 1920–40*—*Continued*

State and County	Township	Origin[1]	1927	1928	1929	1930	1931	1932	1933	1934	1935	Total[2]
Ohio—Cont'd.												
Champaign	Salem	E	0	0	0	0	0	0	0	2,062	0	2,062
Clark	Moorefield	E	0	0	0	0	0	0	0	0	1,991	1,991
Crawford	Liberty	E	0	0	0	0	0	0	0	1,489	0	1,489
Defiance	Washington	E	0	0	0	0	0	0	0	1,791	0	1,791
Delaware	Liberty	E	0	0	0	0	0	0	0	0	1,996	1,996
Erie	Perkins	E	172	3,202	0	0	0	0	0	0	0	3,374
Do	Vermillion	E	0	0	0	2,049	0	0	0	0	0	2,049
Fulton	German	E	0	0	0	0	0	0	0	1,795	0	1,795
Geauga	Huntsberg	E	0	0	0	2,047	0	0	0	0	0	2,047
Hancock	Marion	O	0	0	0	2,205	1,849	1,024	0	0	0	5,078
Hardin	Liberty	E	0	0	0	2,056	0	0	0	0	0	2,056
Henry	Damascus	E	0	0	0	0	0	7	0	0	0	7
Do	do	O	0	0	0	5,760	6,504	6,884	0	0	0	19,148
Huron	Richmond	E	0	0	0	3,058	4,128	2,085	0	0	0	9,271
Knox	Pike	E	0	0	0	0	0	0	0	0	1,995	1,995
Lake	Mentor	E	0	2,382	0	0	5,217	0	0	0	0	7,599
Logan	Richland	E	0	0	0	0	0	0	0	1,798	0	1,798
Lorain	Avon	E	0	0	0	0	0	0	0	0	1,996	1,996
Lucas	Jerusalem	E	653	2,973	904	0	0	0	0	0	0	4,530
Do	do	O	0	0	1,129	0	0	0	0	0	0	1,129
Madison	Pike	E	0	0	0	0	0	0	0	0	2,996	2,996
Do	Stokes	E	0	0	0	0	0	0	0	0	2,993	2,993
Marion	Scott	E	0	0	0	2,048	0	0	0	0	0	2,048
Medina	Chatham	E	0	0	0	2,382	0	0	0	0	0	2,382
Mercer	Jefferson	E	0	0	0	0	0	0	0	0	1,983	1,983
Miami	Newberry	E	0	0	0	0	0	0	0	0	1,992	1,992
Morrow	Westfield	E	0	0	0	0	0	0	0	0	1,997	1,997
Ottawa	Danbury	E	0	0	0	2,375	4,440	0	0	0	0	6,815
Paulding	Brown	E	0	0	0	0	0	0	0	2,389	0	2,389
Portage	Charlestown	E	0	0	0	2,073	0	0	0	0	0	2,073
Putnam	Jennings	E	0	0	0	2,373	1,619	2,069	0	0	0	6,061
Do	Monroe	O	0	0	0	374	0	0	0	0	0	374
Richland	do	E	0	0	0	1,776	0	0	0	0	0	1,776
Sandusky	Ballville	E	0	0	0	0	0	0	0	2,795	0	2,795

Seneca	Seneca	E	0	0	0	2,347	0	0	0	0	0	2,347
Shelby	Jackson	E	0	0	0	0	0	0	0	0	1,992	1,992
Stark	Marlboro	E	0	0	0	0	0	0	0	0	1,976	1,976
Summit	Bath	E	0	0	0	2,098	5,035	0	0	0	0	7,133
Do	Northampton	E	0	0	0	2,016	5,265	0	0	0	0	7,281
Trumbull	Bazetta	E	0	0	0	2,089	0	0	0	0	0	2,089
Union	Claiborne	E	0	0	0	0	0	0	0	2,380	0	2,380
Van Wert	Willshire	E	0	0	0	2,370	2,445	0	0	0	0	4,815
Wayne	Canaan	E	0	0	0	0	0	0	0	0	1,991	1,991
Williams	Madison	E	0	0	0	0	0	0	0	2,196	0	2,196
Wood	Perry	E	0	0	0	0	0	0	38,002	0	0	38,002
Do	do	O	0	0	0	0	0	0	119	0	0	119
Do	do	D	0	0	0	0	0	0	19	0	0	19
Do	Webster	E	0	0	0	0	0	24,806	0	0	0	24,806
Wyandot	Jackson	E	0	0	0	2,088	0	0	0	0	0	2,088
Total			825	8,557	2,033	47,726	36,502	36,875	38,140	20,792	25,898	217,348
Pennsylvania:[7]												
Centre	Miles	O	0	0	0		0	0	0	0	0	1,965
Crawford	Greenwood	E	0	0	13		0	0	0	0	0	13
Do	Wayne	E	0	1,689	0	2,081	0	0	0	0	0	3,770
Erie	Harborcreek	E	0	0	395	0	0	0	0	0	0	395
Do	do	O	0	0	1,254	0	0	0	0	0	0	1,254
Do	Springfield	E	0	0	0	2,096	0	0	0	0	0	2,096
Warren	Broken Straw	E	0	0	0	2,095	0	0	0	0	0	2,095
Total			0	1,689	1,662	6,272	0	0	0	0	0	11,588
Rhode Island:												
Newport	Portsmouth	E	0	0	0	0	0	2,465	1,806	0	0	4,271
Do	do	O	0	0	0	0	0	193	3	0	0	196
Do	do	D	0	0	0	0	0	732	996	0	0	1,728
Providence	E. Providence	E	0	2,795	1,670	5,990	15,591	0	0	0	0	26,046
Do	do	O	0	0	646	109	1,508	0	0	0	0	2,263
Do	do	D	0	0	0	93	696	0	0	0	0	789
Total			0	2,795	2,316	6,192	17,795	3,390	2,805	0	0	35,293

TABLE 15.—*Numbers of Lydella stabulans grisescens adults released in the United States, 1920–40—Continued*

State and County	Township	Origin[1]	1927	1928	1929	1930	1931	1932	1933	1934	1935	Total[2]
Vermont:												
Grand Isle	Grand Isle	E	0	0	0	0	0	0	0	0	3,960	3,960
Rutland	Poultney	E	0	0	0	0	0	0	0	0	1,961	1,961
Washington	Middlesex	E	0	0	0	0	0	0	0	0	1,953	1,953
Windsor	Bridgewater	E	0	0	0	0	0	0	0	0	1,939	1,939
Total			0	0	0	0	0	0	0	0	9,813	9,813
Virginia:												
Accomac	Lee	E	0	0	0	0	0	0	0	0	1,977	1,977
Northampton	Frankton	E	0	0	0	0	0	0	0	0	1,979	1,979
Total			0	0	0	0	0	0	0	0	3,956	3,956
Grand total			10,935	27,519	21,830	172,969	132,611	129,779	60,747	38,559	92,922	702,037

[1] D, Domestic; E, from Europe; O, from the Orient.

[2] The totals in this column include the numbers given in the footnotes to this table.

[3] In 1937, 1,987 flies of domestic origin were liberated in Fairfield Township, Fairfield County.

[4] In 1936, 5,365 flies of domestic origin were liberated in Newark Township, Worcester County.

[5] The following numbers from Europe were liberated in the State in other years: In 1920—70 flies in Watertown Township, Middlesex County; in 1921—300 in Malden Township, Middlesex County; in 1922—62 in Malden Township, Middlesex County; in 1925—172 in Arlington Township, Middlesex County, and 14 in Medford Township, Middlesex County; in 1926—1,034 in Saugus Township, Essex County, 1,714 in Medford Township, Middlesex County, and 283 in Revere Township, Suffolk County.

[6] In 1936, 810 flies were liberated in Woodland Township, Burlington County; in 1937, 270 in the same township, and in 1939, 120 flies in Burlington Township, Burlington County; all of domestic origin.

[7] In 1936, 1,965 flies from the Orient were liberated in Miles Township, Centre County.

FIELD STATUS

When introduced into the Lake States area in 1927, *Lydella stabulans grisescens* showed good initial establishment on the 1-generation strain of the borer. Maintenance was obtained, however, only in close proximity to Lake Erie. Surveys made over a number of years demonstrated that not only was this parasite confined to districts contiguous to the Lake, but it was specifically confined to sections bordering on fresh-water marshland. No explanation for this definite association with the marsh has been obtained to date. A study of the more or less closely related insect fauna of the marsh has revealed no alternate host, a fact which might explain the concentration of the species in such districts. *L. stabulans grisescens* never has been recovered, so far as is known, from any host other than *Pyrausta nubilalis* in the United States, nor has the closely related native species *Lydella nigrita* ever been reared from *P. nubilalis.* All larvae and puparia not referable to adult males and all female flies are therefore determined as *L. stabulans grisescens* if reared from *P. nubilalis* and as *L. nigrita* if obtained from any other host.

In the vicinity of certain release points located near marshland, notably those in Jerusalem Township, Lucas County, and Perkins Township, Erie County, Ohio, and in Erie Township, Monroe County, Mich., parasitization by this species has increased more than anywhere else in the United States and compares very favorably with the highest records from the countries of its origin. Surveys conducted at the close of the 1938 season showed that equilibrium between host and parasite had not been reached prior to that year at any of the three above-named points. The data on parasitization at the Jerusalem Township, Lucas County, release site (table 16) indicate the steady increase in density near the liberation center.

TABLE 16.—*Annual fall parasitization of the European corn borer by Lydella stabulans grisescens at the Jerusalem Township, Lucas County, Ohio, release point*

Year	Parasitization within radius of release	
	3.5 miles	7.5 miles
	Percent	*Percent*
1932	0.3	
1933	2.8	
1934	6.3	
1935	7.6	4.4
1936	10.0	7.0
1937	17.1	9.6
1938	20.9	13.0

Collections made in 1938 to determine the distribution of *Lydella stabulans grisescens* in the vicinity of marshland along the bays and inlets of the Lake Erie and Detroit River shore line showed this larvaevorid to be present in greater or less density from the Huron River east of Sandusky, Ohio, to the outskirts of Detroit, Mich., a distance of over 130 miles. Within this strip

are several release points, and the survey showed a fairly uniform decrease in density of the parasites as the distance from the release points increased, indicating that dispersion was still taking place. This is further borne out by data from the Jerusalem Township, Lucas County, site, which was surveyed in 1938 by utilizing a polar-coordinate design, the three inner rings of which were 1 mile and each of the outer two, 2 miles wide, shown in the following tabulation:

Area surveyed:	*Borers parasitized* *Percent*
Inner circle	24.6
First ring	22.4
Second ring	16.7
Third ring	2.7
Fourth ring	6.1
Average	14.5

At this location the five highest percentages of parasitization, principally by *Lydella stabulans grisescens,* were 81.8, 81.7, 61.4, 58.8, and 57.1. Eleven of the sections showed parasitizations of over 40 percent.

While making borer collections in the fall to determine the status of parasites, puparia of the first generation of *Lydella stabulans grisescens* were encountered. In the Lake States area all ectoparasites and endoparasites that had issued from the hosts prior to the collection were included in the samples, since such parasites were responsible for the death of borers which, excluding other mortality factors, would have overwintered and produced moths the following spring. In 1938 in this area, a greater proportion of *L. stabulans grisescens* had issued from their hosts prior to the time of collection than in any of the preceding 4 years.

The total *Lydella stabulans grisescens* that issued prior to the October collection in the years 1934, 1935, 1936, 1937, and 1938 were 63.8, 64.6, 83.8, 72.1, and 86.3 percent, respectively.

There was a considerable variation in the proportion of parasites issuing prior to October each year, that of 1938 being about 35 percent greater than the proportion in 1934. The cause of this variation is not known, nor was its effect on the next generation observed. Each year a certain proportion of the puparia taken in the field in October was found to have been attacked by hyperparasites. In 1938 14.1 percent were hyperparasitized. Prior to collection, adult chalcids had emerged from over 80 percent of the puparia so attacked. Parasites in the remaining puparia hibernated and emerged in the incubator room soon after being placed in a developmental environment in March. The average number of hyperparasites per puparium was 7.9.

Apparently there was no association between the proportion of hyperparasites overwintering in the puparia and the locality from which they were collected. Chalcid adults reared from *Lydella stabulans grisescens* puparia were determined by C. F. W. Muesebeck as *Eupteromalus dubius* (Ashm.). It was noted that the hyperparasites could attack the puparia successfully when no metamorphosis had taken place or when transformation had

progressed to the point where setae and appendages of the adult fly were well developed.

All puparia from which adults had not emerged at the time collections were made in October, except those attacked by hyperparasites, were found to have died from an unknown cause. Most of the specimens from the Ohio shore of Lake Erie had died after transforming to adults, whereas those from Michigan had died while still in the larval stage. This fact seems to indicate that the puparia were killed at the advent of cold weather and that those originating in a slightly warmer district had time to develop further than did those collected at points farther north.

The percentage of dead and hyperparasitized puparia in 1938 closely approximated those of 1937, when 20.68 percent of the total had failed to emerge and 11.51 percent were killed by hyperparasites. Thus a mortality of approximately one-third of the puparia formed before winter appears to be the normal occurrence and may constitute an intrinsic weakness restricting the rate of increase of *Lydella stabulans grisescens* in the Lake States.

In the Eastern States area, association of *Lydella stabulans grisescens* with marshland is not so clearly demonstrated, the parasite being more generally and uniformly distributed.

In the vicinity of the earliest release points, that is, those centering at Malden, Mass., releases were made yearly throughout the period 1920–32, except in 1923 and 1924. It is not definitely known when initial establishment at this point was effected.

The first record of this parasite's recovery was in the spring of 1927 from Saugus, Mass., but it may have become established prior to that date and following its initial release. In 1928, 1929, and the first part of 1930, *Lydella stabulans grisescens* was the most abundant parasite in this area, but later this position was assumed by the imported ichneumonid *Horogenes punctorius*. However, *L. stabulans grisescens* was more or less abundant each year up to 1938. In the fall of that year it was found that this larvaevorid had almost entirely disappeared from a considerable area northwest of Boston, where it had formerly been abundant. Only a single specimen was recovered from a collection of over 3,000 host larvae. The species was found to be present in 1938 at all other points at which it had been released.

In the vicinity of Taunton, Mass., where a survey was made in 1938 covering an area of about 1,600 square miles and including the territory influenced by the release points at Bridgewater, Dighton, and Swansea, Mass., and at Portsmouth and East Providence, R. I., this parasite was found to be more evenly dispersed than previously. It was recovered from 52, or 50.5 percent, of the 103 collections in 1938, as compared to 31, or 32.3 percent, of the 96 collections from approximately the same area in the fall of 1937. The average parasitization of borers in this area increased from 1.2 percent in 1937 to 5 percent in 1938. The area over which it was found was also somewhat increased. Figure 16, *D*, shows the distribution of *Lydella stabulans grisescens* around Taunton, Mass., as determined by the fall surveys made in 1937, 1938, and 1939.

At East Hartford, Conn., where adults from both Europe and the Orient were released in 1934, *Lydella stabulans grisescens* was

recovered from 12 of the 36 collections made within a 4½-mile radius of the point in 1938. Within 6 years after its release, it had dispersed to the limit of the area surveyed in 1940. The highest parasitization was recorded from a field at the periphery of the surveyed area. The exact extent or rate of spread is not known.

At the Atlantic, N. J., site, where *Lydella stabulans grisescens* was released in 1935, small numbers have been recovered each year.

On the Eastern Shore of Virginia colonies of this parasite were released at two sites in 1935. At one of these sites, Lee Township, Accomac County, this larvaevorid was recovered at the close of the 1938 season from all but 3 of the 40 collections made within a circle 9 miles in diameter, centering at the release point. The average parasitization was 9.5 percent of the 1,879 host larvae observed from the 64-square-mile area surveyed, as compared with only 0.6 percent in a smaller area in the fall of 1937. Not only was there a decided increase in the percentage of borers parasitized (possibly partly due to a greatly decreased host population), but an extensive dispersion of *Lydella stabulans grisescens* also took place. Although the area surveyed was increased from approximately 38 square miles in the fall of 1937 to over 60 square miles in 1938, the number of parasites obtained from hosts collected near the boundary of the area indicated that the parasites had dispersed beyond its limits. This is also indicated by the fact that *L. stabulans grisescens* parasitized as great a proportion of the borers near the periphery of the survey as in the central district. This information is summarized in table 17. The center circle, 1 mile in diameter, was surrounded by 4 rings, each 1 mile wide.

TABLE 17.—*European corn borer parasitization by Lydella stabulans grisescens in Lee, Va., area, fall of 1937 and 1938*

Area surveyed	European corn borers		
	Observed	Parasitized	
1937	*Number*	*Number*	*Percent*
Inner circle	77	9	11.7
Second circle	439	28	6.4
Third circle	687	61	8.9
Fourth circle	357	48	13.4
Fifth circle	319	33	10.3
1938			
Inner circle	516	37	7.2
Second circle	1,203	98	8.1
Third circle	1,560	146	9.4
Fourth circle	1,879	179	9.5

The district surveyed in the fall of 1938 at Lee, Va., extended almost across the rather narrow peninsula that constitutes the Eastern Shore of Virginia. The shores of this peninsula are bordered by extensive marshlands, with numerous creeks extend-

ing throughout the area, and it is in such ecological habitats as this that *Lydella stabulans grisescens* has been most effective in the Lake States. An examination of the data does not indicate greater effectiveness of the parasite in collections made very near marshland, but the marshland influence may extend throughout the area surveyed. Because of its recent establishment in this area, the parasite probably has not yet reached its equilibrium position.

It is believed that the dispersion of *Lydella stabulans grisescens* in the Lake States area closely approximates the entire extent of the parasite's range in that area at the close of the 1938 season.

In the east, however, the area inhabited by *Lydella stabulans grisescens,* as determined by the 1938 surveys, may represent only a portion of the parasite's total range. Most of the colony sites in the Eastern States have never been examined and at a number of them this parasite may be present, since no known environmental limitation restricts the establishment of the species in the East as the absence of marshland apparently does in the Lake States.

SHIPMENTS OF LYDELLA STABULANS GRISESCENS TO OUTSIDE LABORATORIES

During the progress of colonization activities, some shipments of adults of *Lydella stabulans grisescens* were made to laboratories other than those concerned with corn borer activities. The material usually became available in connection with colonization of other species. In 1935, 10,000 adults were shipped to Houma, La., for a test release against the sugarcane moth borer (*Diatraea saccharalis* F.). In the same year 10,000 adults were shipped to Tempe, Ariz., for a test release against the southwestern corn borer (*D. grandiosella* Dyar). In 1936, 3,000 adults were sent to Mayaguez, P. R., for testing against the sugarcane moth borer. In 1937 a consignment of 405 adults of this larvaevorid were shipped to Presidio, Tex., to combat the pink bollworm (*Pectinophora gossypiella* Saund.).

RÉSUMÉ OF THE STATUS OF LYDELLA STABULANS GRISESCENS

Over the entire corn borer infested area *Lydella stabulans grisescens* probably kills more borers than does any other imported parasite. It reaches its maximum effectiveness in the immediate vicinity of the marshland bordering the shore line at the western end of Lake Erie and along the Detroit River. However, in the Lake areas, unless climatic or other factors change, producing conditions more favorable to the parasite than those that have existed since colonization, probably *L. stabulans grisescens* will not increase to a level of economic importance except in a limited area adjacent to marshland. One factor that may increase its general effectiveness is the tendency of its host in the Lake States toward an increasing prevalence of a 2-generation habit.

It appears possible that in areas in the United States where the borer has more than two generations a year, *Lydella stabulans*

grisescens may become an effective factor in control. This is indicated by a report from Guam. A stock of *L. stabulans grisescens* (*Ceromasia lepida* (*Masicera senilis*)) had been collected in Japan by C. A. Clark and shipped to Guam in 1930. Vandenburg (*43*) states: "It [*Ceromasia lepida*] appears to be a very efficient parasite under these conditions, approaching the danger point of self-extermination in the most favorable localities".

This parasite disperses at a maximum rate of about 2 miles per year in the Lake States area, and probably much faster in parts of the East.

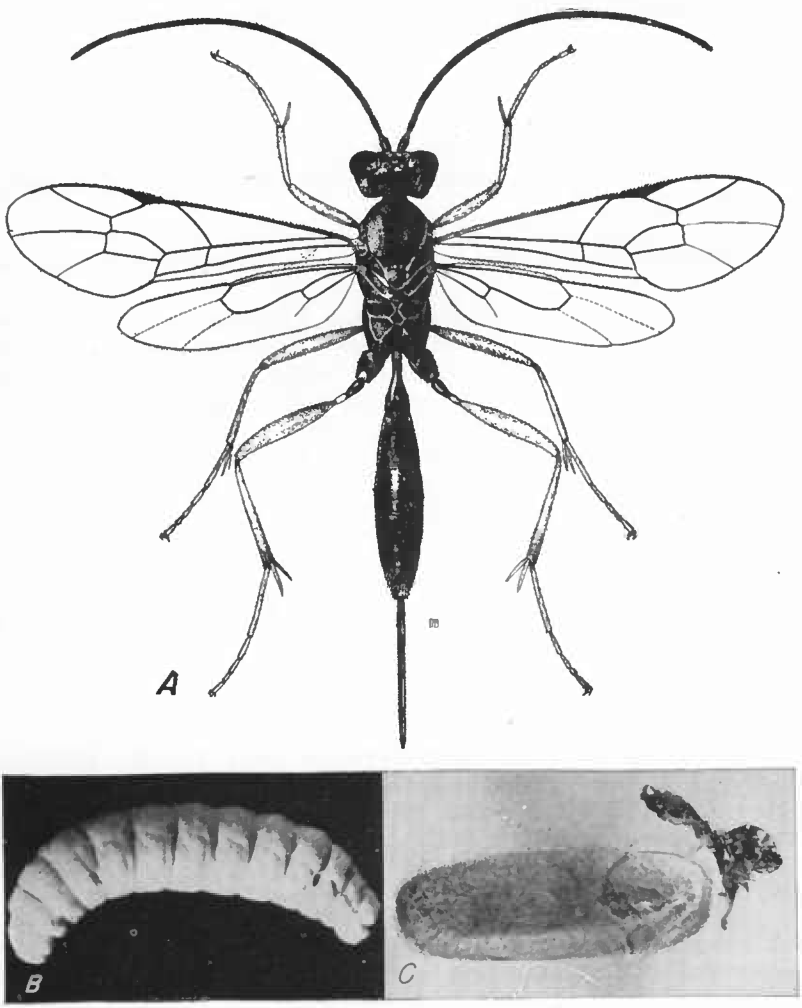

FIGURE 18.—*Horogenes punctorius*: *A*, adult female, × 5; *B*, mature larva, × 8; *C*, cocoon with host (European corn borer) remains.

HOROGENES PUNCTORIUS (Roman) (Fig. 18)

Order: Hymenoptera.
Family: Ichneumonidae.
Imported from: Europe and the Orient.
Preferred host stage: Second-, third-, and fourth-instar larvae.
Method of parasitization: Oviparous; eggs laid free in body cavity of host.
Hibernation: First-instar larva within mature host larva.

No treatise dealing specifically with the life history or biology of *Horogenes punctorius* has been published. The following information on the biology and habits of this ichneumonid was obtained in the United States, either through research directed to that end or incidentally during colonization activities.

ORIGIN

Adults of this species for colonization in the United States originated in Europe and the Orient. In each of these regions *Horogenes punctorius* was found in both the 1- and the 2-generation areas of the host. In Europe it is more abundant in the warmer sections, where the host has two generations each year and all the material imported into the United States from Europe was contained in 2-generation hosts. In the Orient, however, *H. punctorius* is important only in the colder sections, and most of the importations were from the 1-generation area.

DESCRIPTION OF STAGES

Adult

The original description of *Horogenes punctorius*, under *Angitia* (*Dioctes*) *punctoria* n. sp., is given by Roman (*29, pp. 171–172*). Reproductions of the original descriptions, together with additional notes which are helpful in classifying the species, were published by Ellinger and Sachtteben (*13, pp. 116–117; 14*). It more closely resembles *Campoplex alkae* than any other corn borer parasite, but, since it has no areolet in the forewings, it can readily be distinguished from that species.

Egg

The egg of *Horogenes punctorius* 18 hours after deposition averages 0.730 mm. long by 0.173 mm. wide at the larger end and 0.147 mm. wide at the narrow end. It is oval arcuate, with broadly rounded ends. It is white, and there are no spines, processes, or markings of any kind on the chorion. The egg does not turn dark brown at the end of a few days, as does that of *Campoplex alkae*.

Dissections, at 4-hour intervals, of European corn borer larvae parasitized in the laboratory and reared at a temperature of 80° F. and 70 percent relative humidity showed that *Horogenes punctorius* eggs hatch in 32 hours.

First-instar Larva

The primary larva is of the typical ichneumoniform type. It is cylindrical, with no segmentary spines, tubercles, or appendages. The head is heavily chitinized, and there are 13 body segments. The last abdominal segment is prolonged into a conical pointed tail about half as long as the rest of the body.

Second-instar Larva

The secondary larva is larger and has a less heavily chitinized and more rounded head than the primary larva. At the time of molting into the second instar the tail process is lost. It is not absorbed by the larva.

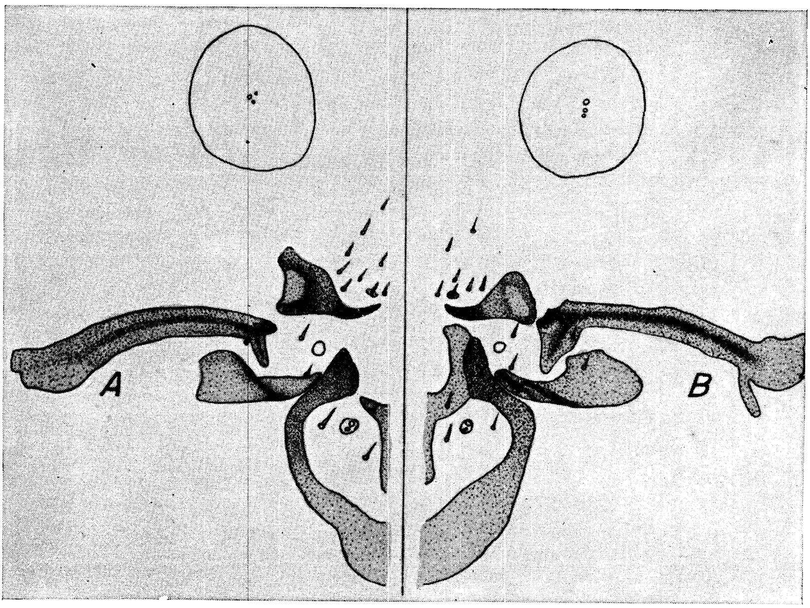

FIGURE 19.—External structures and markings of heads of last-stage larvae: *A, Campoplex alkae; B, Horogenes punctorius,* × 133. (Vance and Smith, 42).

Mature Larva

The general color of the mature larva is a dirty white. It is subcylindrical and tapers slightly anteriorly and posteriorly (fig. 18, *B*). In gross appearance it is similar to the larva of *Campoplex alkae,* the chief differences appearing in the characters around the buccal regions. The front views of the head capsule of the third-stage larva of *C. alkae* and *Horogenes punctorius* are shown in figure 19, wherein the following differences between the two species may be noted.

1. Interior angle at union of tip of mandible with its base obtuse or rounded; ligular sclerome extensive, broadly approximat-

ing dorsal ends of labio stipital sclerome; stipital sclerome at median point as broad or broader than hypostoma.
Horogenes punctorius

2. Interior angle at union of tip of mandible with its base acute and clearly defined; ligula sclerome, small and subcrescent shape; stipital sclerome at median point narrower than hypostoma.
Campoplex alkae

Cocoon

The cocoon of *Horogenes punctorius* is uniformly dirty white and consists of a closely woven outer covering of silk threads enveloping a dark-brown, glossy, secretitious lining (fig. 18, *C*). Its average dimensions are 11.3 by 3.5 mm. Apparently there is no difference in color or texture between the first- and second-generation forms. The *H. punctorius* cocoon normally lacks the light-colored band noticeable in cocoons of *Campoplex alkae,* but an occasional *H. punctorius* cocoon shows a slight trace of this band. The exit hole is usually made at the end of the cocoon, the entire end being gnawed away at the time of emergence.

BIOLOGY

Mating

Both males and females mated on the day they emerged. The males copulated at any time throughout their life. Females were observed to mate only during the first 3 days after emergence. Mating was obtained in the laboratory in a cloth-covered cage, with one end directed toward and close to a window. Copulation was noted at temperatures between 70° and 82° F. No attempt was made to ascertain the temperature limits at which the parasites would mate. After males had been placed with females in a cage, they usually mated within 5 to 30 minutes, but in one cage 55 minutes and in two other cages 4 hours elapsed before mating took place.

Copulation was always preceded by certain activities. The male, after becoming aware of the presence of the female at a distance usually less than 1 inch, approached her slowly with rapidly vibrating wings. This vibration sometimes continued almost a minute, as the male gradually came closer. He then stroked the female with his antennae and, unless she resisted, copulation took place. When in coitu the female remained quiet for a time except for a slight vibration of the antennae. The ovipositor, which normally is in a horizontal position, extended vertically after contact was made. During copulation the male faced in the direction of the female with the abdomen thrust forward. In most cases after being in coitu a few minutes the abdomen of the female was jerked rythmically, the pulsations being about 1 per second. In 56 instances observed in the laboratory the average length of time the adults remained in coitu was 7.9 minutes.

At the end of the mating period the female often dragged the male a considerable distance before they separated. An unmated female often resisted mating attempts by pushing the male off and walking or flying away. A female that had mated normally, however, would turn on the male and actively attack him and attempt to sting. Such action differed markedly from the passive resistance shown by unmated females and is a good indication that females normally mate but once. This view is supported by the fact that only one female was observed to mate twice and this was accomplished only after many attempts. The males will copulate several times and will court mated or unmated females without discrimination.

Proportion of Sexes

Of 141 individuals, the offspring of females mated in the laboratory, 34.04 percent were females. The sex proportions in material collected in Europe and shipped to the United States in the cocoon stage during the summer was almost opposite to that of the laboratory-reared individuals. In 5 lots of cocoons, totaling 986 specimens, received in August, 64.5 percent were females, but some males may have emerged in the field prior to collection.

Oviposition

The preoviposition period is normally of short duration. Successful oviposition was obtained in the laboratory the day after emergence. The females oviposted in confinement on either free-crawling larvae or larvae offered them on a camel's-hair brush. They showed much interest in borer frass or webbing and also showed great ability to locate such material. One female flew out of the cage, circled the room, and returned to host material in the cage.

Oviposition by *Horogenes punctorius* on host borers in their natural habitat was observed in life-history cages. These cages, screened with 24-mesh copper screening, measured 10 by 6 by 6 feet and were set up over two rows of corn of six hills each (fig. 17). The corn was artificially infested to produce a high population of host larvae. Females released in such cages showed interest in larvae webbed in the tassels. The ovipositors were thrust easily through the webbing and pierced the leaf sheath. The females also worked around frass at the entrance to tunnels. Although the larvae concealed among the tassel florets were more accessible, dissections of the host plants indicated that some, if not most, of the parasitized borers were in other parts of the plant. Stalks dissected at the end of the first week after adult parasites were released in the cage showed borers from various parts of the plant parasitized in the percentages shown in table 18.

Most of the parasitized borers were in the middle of the plant. Although these borers may have migrated down the stalk after being parasitized in the tassel, the shortness of the time interval between the parasite releases and dissection of the stalk indicates that most, if not all, of them were in the same position when parasitized as when removed from the plants. These observa-

TABLE 18.—*Parasitization by Horogenes punctorius of European corn borers dissected from different parts of host plant*

Plant part	Number of borers		Percent of total borers parasitized
	Present	Parasitized	
Tassell	5	1	2.5
Stalk:			
Upper third	7	4	9.3
Middle third	23	18	44.0
Lower third	8	3	7.2
Total	43	26	62.5

tions were made at Toledo, Ohio, on 1-generation hosts. In the East, where the 2-generation type of borer prevails, most of the cocoons of the first-generation parasites were found in the tassel stem; therefore either parasitization takes place in the tassel or tip of the cornstalk or the parasitized borers make a definite migration to this part of the plant.

Horogenes punctorius deposits its egg free in the body cavity of the host larva. In both the laboratory and the field, females were seen to oviposit more than once in a single host larva. The supernumerary eggs hatched but the resulting larvae became encysted, turned dark, and died without developing. Before ovipositing, the female touched with rapidly vibrating antennae the free-crawling host larva or the spot in webbing, frass, or leaf that she was investigating. The ovipositor and posterior end of the abdomen were then bent downward at a right angle, or slightly less, to the line of the body. The actual time required for egg deposition is very short. One female parasitized 33 larvae in 45 minutes. When ovipositing on other than a free-crawling larva the female may repeatedly insert the ovipositor at different angles into the hiding place of the host until contact is made. Oviposition was accomplished readily in second-, third-, and fourth-instar hosts, but with difficulty in fifth-instar hosts, apparently because of the toughness of the skin. When eggs were deposited in a mature borer, however, development of the egg and larva proceded normally.

Dissection of larvae in the field cages soon after parasite adults had been introduced showed that parasitized individuals were most numerous among the third-instar borers. This may have resulted from the greater accessibility of the third-instar or well-advanced second-instar borers, or from the selection of such borers by the parasite.

That *Horogenes punctorius* females do not seek out the most heavily infested fields in preference to those less heavily infested, is indicated by data collected at Medford, Mass., in 1932. Two fields about 200 yards apart were infested at the rate of 5,120 and 1,373 borers per 100 stalks, respectively. The parasitization in the more heavily infested field was 1 percent and in the other, 4 percent, or about the same number of parasites per 100 stalks in each field. These percentages indicated that about the same number of parasites entered each field, since the low parasitiza-

tion, coupled with the high host population even in less heavily infested fields, probably reduced to a minimum the variation due to the search factor.

Longevity of Adults

Limited observations on 37 individuals indicated that female parasites live longer than males. The adults were fed granulated sugar and water and were confined in cages in an incubator room held at a temperature of 80° F. and 70 percent relative humidity. The average length of life of the males was 12.8 days. The life of mated females that were given opportunity to oviposit averaged 16.2 days, but the average for those that did not mate or oviposit was 26.5 days. In the field cages only females were found alive at the end of 10 days following introduction of 2-day-old adults.

Parthenogenesis

Viable eggs were laid by unmated females, but in all cages observed only males hatched from them.

Larval Development

Like the egg, the newly hatched larva floats free in the body fluids of its host, and is carried to all parts of the host's body. The larva spends most of its life in the first instar. When reared in the laboratory (temperature 80° F. and 70 percent relative humidity), the average larval life of 225 individuals was 14.9 days, ranging from 10 to 29 days, and 63.9 percent of the parasite larvae issued from their hosts on the twelfth to seventeenth day.

Dissection showed that the parasite did not pass from the first instar until the host had reached the fifth instar. Development in many instances was probably incited by physiological changes in the host larva as it prepared for pupation, because, although the host reached the fifth instar in the field in August, the parasite passed the winter as a first-instar larva. There was a distinct and appreciable tendency of the parasite to follow the diapause requirement of the host. On the single-generation type of host in the field, only a small percentage of the parasites developed to adults during the summer, the others remaining in the first instar until the host became active the following year. Even in the laboratory there was great variation in the length of the instars of *Horogenes punctorius* larvae reared on single- generation borers. Parasites in all instars were found in host larvae 20 days after parasitizing them, although all the host larvae were reared under the same conditions, and were parasitized in the same instars by the same females.

Parasitized larvae obtained from cornstalks in a field cage and placed in an incubator (80° F., 70 percent relative humidity) on January 6, produced the first cocoons 23 days later, the average time for 27 individuals being 32.1 days. Since the total length of the egg and larval stages under similar incubator conditions

averaged less than 17 days, it is apparent that there was a lag either in the incitation of development or in the rate of development produced by exposure to cold. Possibly the causative delay factor in the above instances originated in the host.

Parasitization by *Horogenes punctorius* retards the growth of the host, even though the parasite larva remains in the first instar throughout the normal feeding period of the host and grows very slowly. After the first instar the parasite larva develops rapidly, spending but a few days in the second and third instars. The parasite usually issues from the anterior third of the host's body, but before the termination of feeding it has consumed all but the head capsule and the shriveled larval skin.

Cocoon Stage

After the parasite has completed its feeding, it spins its cocoon, usually including the remains of the host in the loose strands of the outer envelope. The average length of the cocoon stage, as determined from records of 190 individuals (about two-thirds of which were males) reared at a temperature of 80° F. and 70 percent relative humidity, was 9.4 days. Approximately 86 percent of the adults emerged on the ninth and tenth days after the formation of the cocoons.

SEASONAL HISTORY

The total period from deposition of the egg to emergence of the adult, based on observation of 190 individuals reared at a temperature of 80° F. and 70 percent relative humidity, was 25.3 days. Dissection of host larvae taken in the field near Toledo, Ohio, showed very little development before the second week in June. Development is rapid after about June 10 and the first cocoon appeared on June 16. In field cages the first adult appeared on June 24, and this date coincides closely with that of field emergence as determined by field collections. In Ohio the average length of the life cycle of individuals that undergo one generation in the field in the summer is about 36 days.

Hyperparasitism

Cocoons imported from Europe in August were found to be parasitized by a number of hyperparasites. In none of the shipments, however, did the aggregate parasitization amount to 1 percent of the total. The species involved were *Gelis fraudulentus* (Foerst), *G. instabilis* Foerst, *Otacustes aestivalis* (Grav.), and an undetermined chalcid. On cocoons of the summer generation in eastern Massachusetts a higher rate of hyperparasitization was noted in 1938, when 8 percent of the unemerged cocoons collected in the field were attacked by parasites. The three species obtained were *Mastrus compactus* (Ashm.), *Itoplectis conquisitor* (Say), and *Gambrus ultimus* (Cress.). The last two species were recorded, also, as primary parasites of the borer.

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TABLE 19.—*Horogenes punctorius adults released in the United States through December 31, 1940*

State and County	Township	Origin[1]	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	Total[2]
Connecticut:														
Hartford	E. Hartford	E	0	0	0	0	0	0	0	750	0	0	0	750
Middlesex	Haddam	E	0	0	0	0	0	0	0	0	586	0	0	586
New Haven	Milford	E	0	0	0	0	0	0	0	827	552	0	0	1,379
New London	East Lyme	E	0	11	0	17	2,226	441	0	0	0	0	0	2,695
Do	do	O	0	0	0	0	7	1,156	0	0	0	0	0	1,163
Do	do	D	0	0	0	0	93	10	0	0	0	0	0	103
Do	Old Lyme	E	206	0	0	0	0	0	0	0	0	0	0	206
Total			206	11	0	17	2,326	1,607	0	1,577	1,138	0	0	6,882
Indiana:														
Allen	Lafayette	D	0	0	0	0	0	0	0	0	0	599	0	599
Steuben	York	E	0	0	0	1,726	2,069	2,194	0	0	0	0	0	5,989
Total			0	0	0	1,726	2,069	2,194	0	0	0	599	0	6,588
Massachusetts:[3]														
Barnstable	Barnstable	E	128	0	0	0	0	0	0	0	0	0	0	128
Do	Falmouth	E	0	16	264	250	1,060	0	0	0	0	0	0	1,590
Do	do	D	0	0	0	0	656	0	0	0	0	0	0	656
Bristol	Dighton	E	0	0	28	0	0	0	0	0	0	0	0	28
Do	Swansea	E	0	49	0	0	0	633	0	0	0	0	0	682
Do	do	O	0	0	0	0	0	2,813	0	0	0	0	0	2,813
Do	do	D	0	0	0	0	0	2,511	0	0	0	0	0	2,511
Essex	Peabody	O	0	0	0	0	0	1,204	0	0	0	0	0	1,204
Do	Saugus	E	0	0	0	0	197	0	0	0	0	0	0	986
Do	do	O	0	0	0	2,029	15	0	0	0	0	0	0	2,044
Do	do	D	0	0	0	0	245	0	0	0	0	0	0	245
Franklin	Bernardston	D	0	0	0	0	0	0	0	0	0	0	575	575
Hampden	Agawam	D	0	0	0	0	0	0	0	0	0	522	0	522
Hampshire	Hadley	D	0	0	0	0	0	0	0	0	0	560	0	560

Middlesex	Arlington	E	0	53	0	0	0	0	0	0	0	0	0	968
Do	do	O	0	0	0	0	0	33	0	0	0	0	0	33
Do	do	D	0	0	0	2	0	0	0	0	0	0	0	2
Do	Concord	E	0	0	0	0	0	1,272	0	481	0	0	0	1,753
Do	do	D	0	0	0	0	0	379	0	5,000	0	0	0	5,379
Middlesex	Malden	E	0	0	0	0	0	0	0	0	0	0	0	186
Do	Medford	E	61	0	0	0	0	0	0	0	0	0	0	2,973
Do	do	O	0	0	0	0	0	502	0	0	0	0	0	502
Norfolk	Quincy	E	249	73	0	0	0	0	0	0	0	0	0	322
Plymouth	Bridgewater	O	0	0	0	0	732	226	0	0	0	0	0	958
Suffolk	Revere	E	0	0	0	0	0	0	0	0	0	0	0	2,721
Worcester	Charlton	D	0	0	0	0	0	0	0	0	0	597	0	597
Total			438	191	292	2,281	2,905	9,573	0	5,481	0	1,679	575	30,938
Michigan:[4]														
Genesee	Genesee	D	0	0	0	0	0	0	0	0	0	0	599	599
Huron	Sebewaing	D	0	0	0	0	0	0	0	0	0	0	558	558
Lapeer	Goodland	D	0	0	0	0	0	0	0	0	0	0	499	499
Lenawee	Fairfield	E	0	0	0	0	0	1,712	0	0	0	0	0	1,712
Livingston	Conway	D	0	0	0	0	0	0	0	0	0	0	394	394
Macomb	Harrison	D	0	0	0	0	0	0	0	0	0	599	0	599
Monroe	Erie	E	0	288	0	0	0	0	0	0	0	0	0	495
Do	Monroe	E	0	33	0	0	917	272	0	0	0	0	0	1,222
Sanilac	Lexington	D	0	0	0	0	0	0	0	0	0	409	0	409
St. Clair	Columbus	E	0	18	243	1,593	1,875	0	0	0	0	0	0	3,729
Tuscola	Koylton	D	0	0	0	0	0	0	0	0	0	598	0	598
Washtenaw	Augusta	D	0	0	0	0	0	0	0	0	0	0	600	600
Wayne	Livonia	D	0	0	0	0	0	0	0	0	0	0	573	573
Total			0	339	243	1,593	2,792	1,984	0	0	0	1,606	3,223	11,987
New Hampshire:														
Rockingham	Raymond	D	0	0	0	0	0	0	0	0	0	0	593	593
New Jersey:[5]														
Atlantic	Egg Harbor	D	0	0	0	0	0	0	0	0	0	0	593	593

TABLE 19.—*Horogenes punctorius adults released in the United States through December 31, 1940*—*Con.*

State and County	Township	Origin[1]	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	Total[2]
New Jersey—Cont'd.														
Burlington	Burlington	D	0	0	0	0	0	0	0	0	0	0	0	608
Monmouth	Atlantic	D	0	0	0	0	0	0	0	0	0	585	0	585
Ocean	Brick	E	0	0	0	0	0	0	0	0	565	0	0	565
Total			0	0	0	0	0	0	0	0	565	585	593	2,351
New York:														
Albany	Berne	E	0	0	0	0	0	0	0	0	517	0	0	517
Cattaraugus Indian Res.		E	0	0	1,256	1,973	0	0	0	0	0	0	0	3,229
Erie	Lancaster	E	0	0	400	0	0	0	0	0	0	0	0	400
Jefferson	Adams	E	0	0	0	0	2,178	539	0	0	0	0	0	2,717
Monroe	Hamlin	D	0	0	0	0	0	0	0	0	0	588	0	588
Niagara	Porter	E	0	0	0	0	0	0	0	0	597	0	0	597
Orleans	Yates	E	0	0	0	0	0	0	0	0	598	0	0	598
Oswego	Scriba	D	0	0	0	0	0	0	0	0	0	593	0	593
Schenectady	Glenville	E	0	0	0	1,793	0	0	0	0	0	0	0	1,793
Suffolk	Southold	E	0	0	0	0	0	1,229	1,289	0	0	0	0	2,518
Do	do	D	0	0	0	0	0	0	2,397	0	0	0	0	2,397
Wayne	Ontario	D	0	0	0	0	0	0	0	0	0	598	0	598
Total			0	0	1,656	3,766	2,178	1,768	3,686	0	1,712	1,779	0	16,545
Ohio:														
Allen	Shawnee	D	0	0	0	0	0	0	0	0	0	587	0	587
Auglaize	Washington	D	0	0	0	0	0	0	0	0	0	593	0	593
Champaign	Salem	D	0	0	0	0	0	0	0	0	0	542	0	542
Darke	Brown	D	0	0	0	0	0	0	0	0	0	578	0	578
Defiance	Washington	D	0	0	0	0	0	0	0	0	0	578	0	578
Delaware	Liberty	D	0	0	0	0	0	0	0	0	0	581	0	581
Erie	Perkins	E	0	0	0	0	0	0	0	0	588	0	0	588

Fulton	German	E	0	0	0	0	0	0	0	0	598	0	0	59[illegible]
Hancock	Marion	O	0	0	0	0	0	4,138	0	0	0	0	0	4,138
Hardin	Liberty	D	0	0	0	0	0	0	0	0	0	586	0	586
Henry	Damascus	E	0	0	0	2,584	4,882	4,858	0	0	0	0	0	12,324
Huron	Richmond	E	0	0	0	0	0	0	0	0	586	0	0	586
Logan	Richland	D	0	0	0	0	0	0	0	0	0	588	0	588
Lorain	Avon	D	0	0	0	0	0	0	0	0	0	525	0	525
Lucas	Jerusalem	E	460	27	511	2,064	2,897	0	0	0	0	0	0	5,959
Marion	Scott	D	0	0	0	0	0	0	0	0	0	514	0	514
Mercer	Jefferson	E	0	0	0	0	0	0	0	0	598	0	0	598
Miami	Newberry	D	0	0	0	0	0	0	0	0	0	598	0	598
Ottawa	Danbury	E	0	0	0	0	0	0	0	0	348	0	0	348
Putnam	Jennings	O	0	0	0	0	0	4,573	0	0	0	0	0	4,573
Sandusky	Ballville	D	0	0	0	0	0	0	0	0	0	0	474	474
Seneca	Seneca	E	0	0	0	0	0	0	0	0	583	0	0	583
Union	Claiborne	D	0	0	0	0	0	0	0	0	0	565	0	565
Van Wert	Willshire	E	0	0	0	0	0	0	0	0	587	0	0	587
Williams	Madison	D	0	0	0	0	0	0	0	0	0	0	600	600
Wood	Perry	E	0	0	0	0	0	0	3,751	0	0	0	0	3,751
Do	do	D	0	0	0	0	0	0	1,523	0	0	0	0	1,523
Total			460	27	511	4,648	7,779	13,569	5,274	0	3,888	6,835	1,074	44,065
Pennsylvania:														
Crawford	Greenwood	E	0	0	707	0	0	0	0	0	0	0	0	707
Rhode Island:														
Newport	Portsmouth	E	0	0	0	0	0	640	430	0	0	0	0	1,070
Do	do	O	0	0	0	0	0	6,038	0	0	0	0	0	6,038
Do	do	D	0	0	0	0	0	1,498	2,636	0	0	0	0	4,134
Providence	E.Providence	E	0	505	0	82	1,503	0	0	0	0	0	0	2,090
Do	do	D	0	0	0	9	1,231	0	0	0	0	0	0	1,240
Total			0	505	0	91	2,734	8,176	3,066	0	0	0	0	14,572
Vermont:														
Chittenden	Essex	D	0	0	0	0	0	0	0	0	0	0	575	575
Rutland	Poultney	D	0	0	0	0	0	0	0	0	0	0	599	599

TABLE 19.—*Horogenes punctorius adults released in the United States through December 31, 1940*—*Con.*

State and County	Township	Origin[1]	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	Total[2]
Vermont—Cont'd.														
Windham	Jamaica	D	0	0	0	0	0	0	0	0	0	0	557	557
Windsor	Bridgewater	D	0	0	0	0	0	0	0	0	0	0	548	548
Total			0	0	0	0	0	0	0	0	0	0	2,279	2,279
Virginia:														
Accomac	Lee	D	0	0	0	0	0	0	0	0	0	595	0	595
Northampton	Franktown	D	0	0	0	0	0	0	0	0	0	593	490	1,083
Total			0	0	0	0	0	0	0	0	0	1,188	490	1,678
Total, United States			1,104	1,073	3,409	14,122	22,783	38,871	12,026	7,058	7,303	14,271	8,827	139,185

[1] D, Domestic; E, Europe; O, the Orient.

[2] The totals in this column include the numbers given in the footnotes to this table.

[3] In 1921, 10 *Horogenes punctorius* from Europe were released in Malden Township, Middlesex County; and 168 in the same township in 1922; in 1924, 555 adults in Arlington Township, Middlesex County; in 1925, 780 flies in Saugus Township, Essex County; 360 flies in Arlington Township, Middlesex County; 8 flies in Malden Township, Middlesex County, and 53 flies in Medford Township, Middlesex County, and in 1926, 9 flies in Saugus Township, Essex County, 2,859 in Medford Township, Middlesex County, 2,721 flies in Revere Township, Suffolk County.

[4] In 1926, 207 adults were released in Erie Township, Monroe County.

[5] In 1938, 182 adults (domestic parasites) were released in Burlington Township, Burlington County, and in 1939, 426 flies were released in the same township.

Alternate Hosts

Larvae of several species of Lepidoptera were offered to *Horogenes punctorius* females in the laboratory in an attempt to obtain oviposition. The parasite adults showed no interest in the larvae of *Gnorimoschema busckiella* Kearf., *Carpocapsa pomonella* (L.), or *Papaipema nebris* (Guen.), but oviposited readily on larvae of *Pyrausta ainslei* Hein. and *P. penitalis* Grote. Whether the parasite could reproduce successfully on these hosts is not known, because none lived to produce either a pupa or a parasite cocoon. *H. punctorius* has never been recovered from hosts other than *P. nubilalis* (Hbn.) in the United States.

COLONIZATION

Horogenes punctorius was also one of the first parasites to appear in the earlier importations from Europe, a colony of 10 adults having been released in 1921 at Malden, Mass., and supplemented by another small colony in 1922. In 1924, 555 adults were liberated at Arlington, Mass., and 4 small colonies were released in 1925 at 4 sites in eastern Massachusetts (table 19). It was not until 1926 that the first releases of over 1,000 adults per colony were made. However, establishment from some of the smaller releases made prior to 1926 was probably accomplished, since the first recovery of the species was made that year at an early colony site sufficiently remote from the current year's releases to make dispersion from the latter points improbable.

The first importation of this species was made during the latter part of the summer when the parasite was in first-generation cocoons. Cocoon shipments were continued through the summer of 1929. Beginning in 1925 the cocoon shipments were supplemented by the introduction of the overwintering hosts with *Horogenes punctorius* as first-instar larvae. After 1929 this was the only method used for introducing *H. punctorius*.

From points in eastern Massachusetts adults of this species appeared more frequently in collections made after 1926 and, beginning with a few individuals in 1930, increasing use was made of this source of supply for colonization. To January 1, 1939, over 30,000 adults derived from hosts obtained in eastern Massachusetts were released in the United States. In 1930 the first releases of adults originating in the Orient were made in Massachusetts.

Colonization of *Horogenes punctorius* in the Lake States area was started in 1926 with a release of 207 adults in Monroe County, Mich. Small releases were made in the following 2 years at this colony site and in Lucas County, Ohio. At the Cattaraugus Indian Reservation in New York in 1929, and after that year at a number of points in the Lake States area, larger colonies were released.

For a number of years *Lydella stabulans grisescens* was the dominant parasite in the vicinity of the older release sites in eastern Massachusetts, but it was eventually superseded by *Horogenes punctorius*. So promising did this parasite appear at these test sites that it seemed advisable to distribute colonies throughout the area where host concentrations warranted releases. Accord-

ingly, in 1935 with adults from European host material, and in 1936 and 1937 with stock of domestic origin, a number of releases were made throughout the East and the Middle West, one colony being liberated per county. By the end of 1939 a total of 89 colonies had been released.

Although *Horogenes punctorius* can parasitize borers of several larval stages, and although these stages may be present in the field over a considerable period, fairly close synchronization of releases with the preferred host stage of the borer is essential for establishment. In 1934, 750 adults of *H. punctorius* were released at East Hartford, Conn., and 827 at Milford, Conn. The periods of release and the extent of synchronization with third-instar corn borers of both the first and second generations are shown in figure 20. Observations on the status of parasites at these two points in the fall of 1935 showed that at East Hartford 3.6 percent of the host borers were parasitized, whereas at Milford no parasite was recovered.

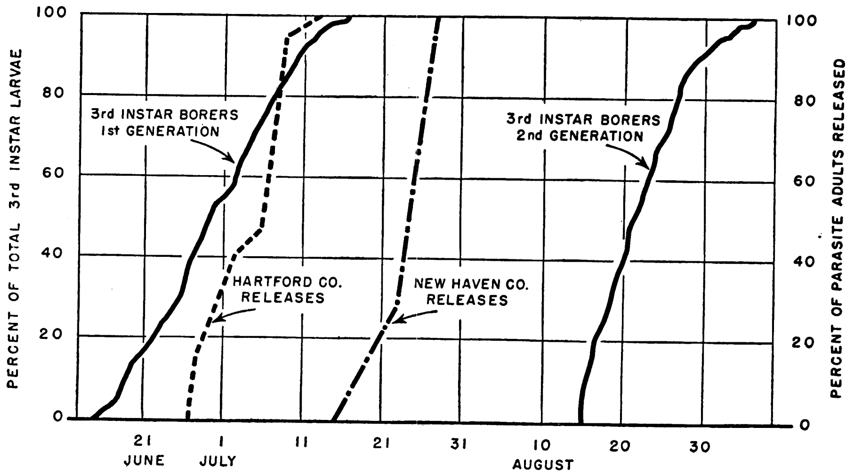

FIGURE 20.—Synchronization of *Horogenes punctorius* releases with presence of preferred stage of host (European corn borer), Hartford and New Haven Counties, Conn.

FIELD STATUS

With proper synchronization, initial establishment of *Horogenes punctorius* was readily accomplished in the areas where the 1-generation strain of the host predominated. Adults appeared in quantity from practically every locality where parasites were liberated. However, in most areas the species maintained itself for 1 year only. At the Cattaraugus Indian Reservation in western New York, *H. punctorius* was recovered over a period of 4 years after the last release in 1930. The percentage of parasitization, however, was always low, never rising above 1 percent. In 1934, 2 specimens were recovered and in 1935 only 1 specimen appeared in a collection of 897 borers from this point. In 1940, however, *H. punctorius* was recovered in several collections of borers from this Reservation, and one collection showed a parasitization of over 10 percent.

The 1940 recovery, showing maintenance for 10 years, demonstrated the ability of the parasite to exist at extremely low levels. In Erie Township, Monroe County, Mich., releases of 207 and 288 adults were made in 1926 and 1928, respectively. No recovery was made until 1933, but after that the parasite continued to appear in small numbers in the collections from this point each year through 1937. In 1938 it was not recovered at any point in the Lake States area. In the eastern area, however, *H. punctorius* has continued to maintain itself and to increase in abundance wherever it was initially established.

Near the colonies west and north of Boston, Mass., where releases were first made in the United States, *Horogenes punctorius* was the only parasite of importance in 1940. At the center of this district it reached its equilibrium position about 1930, but continued to disperse until in the summer of 1938 it was found 25 miles from the center of the colony. A more extended survey might have shown this parasite present over a considerably wider area.

In 1938 and 1939 no surveys were made to obtain data on parasite abundance in the area northwest of Boston for comparison with that of previous years. However, in an area approximately 10 miles square, lying close to the release points and probably representative of the older parts of the area, a survey in 1938 on first-generation borers showed that *Horogenes punctorius* was the most prevalent parasite. Its general distribution was evidenced by the fact that it was recovered in each of 36 collections. The highest percentage of borers parasitized was 55.8, and 6 of the collections showed over 40 percent parasitization. A similar survey in this area in August 1939 showed the parasitization by this species to be 16.2 percent.

In regions where the European corn borer has two generations, parasitization by *Horogenes punctorius* is usually much higher—sometimes about double—on the first, or summer, generation than on the second. In the fall of 1938 the average parasitization, in the 10-square-mile area previously discussed with reference to the first generation, was 12.8 percent. In this survey parasites were again obtained from each of the 36 sections into which the area was divided for study. The highest parasitization by *H. punctorius* in a single collection was 32.6 percent, and 20 of the 36 collections showed a parasitization of over 10 percent. Because of the limited survey in the Malden area in the fall of 1938, no additional information was obtained as to the dispersion of this species.

Following the releases made in the vicinity of Malden, Mass., in the earlier years a group of locations in southeastern Massachusetts and eastern Rhode Island were colonized with *Horogenes punctorius*. A survey to determine the status of the parasite at these locations was made in 1938. It covered a circular area 45 miles in diameter, centering at Taunton, Mass. In that year parasitization by *H. punctorius* on second-generation borers within a radius of 12½ miles of Taunton averaged 1.2 percent, with a maximum parasitization of 7.3 percent. On the first generation of borers in 1938 the average parasitization by *H. punctorius* within the same area was 2.7 percent, with a maximum of 20.2

percent. That the parasite was still increasing in abundance in this area was shown by the increase in parasitization in the summer of 1939, when the average parasitization within a comparable area was 6.3 percent, with a maximum of 30.1 percent.

At the release site at Hartford, Conn., where a colony of 750 adults was released in 1934, *Horogenes punctorius* increased its parasitization of second-generation borers from an average of 3.8 percent in the fall of 1937 to an average of 8.3 percent of the 3,466 hosts observed in the fall of 1938. The maximum parasitization by this species in 1938 was 28.3 percent, as compared with a maximum of 24.5 percent in the fall of 1937. The parasite was reared from 30 of the 38 collections made in 1938, and the area in which it was found increased from 15 square miles in 1937 to approximately 56 square miles in 1938. Figure 21 shows the area occupied by this parasite as revealed in the 1936, 1937, and 1938 fall surveys. The data indicated that *H. punctorius* actually was present over a slightly greater area than that shown on the map, but the district included in the 1938 fall survey was not sufficient to show the full extent of the dispersion of this species in 1938. Three other localities, Atlantic Township, Monmouth County, Burlington Township, Burlington County, N. J., and Lee district, Accomac County, Va., which had been colonized within recent years, were surveyed in the fall of 1938. In New Jersey *H. punctorius* was recovered only at Atlantic. Its recovery at that point indicated maintenance for 2 years and demonstrated the usual slow increase and dispersion for the first few seasons following liberation.

RÉSUMÉ OF THE STATUS OF HOROGENES PUNCTORIUS

Horogenes punctorius is one of the most valuable of the introduced parasites. Initial establishment was readily obtained following releases in both the eastern and western areas, but maintenance of the species is evidenced at present only in the eastern area, except at the Cattaraugus Indian Reservation, in western New York. There is no evidence of superiority in either the oriental or the European strain. At two of the localities in the multiple-generation area, where *H. punctorius* is on a maintenance basis, adults from both sources have been released. That the European stock is capable of maintaining itself is demonstrated by the status of the parasite at Hartford, Conn., where only European material was released. A comparatively small number of the colony sites have been examined, to determine the status of the parasites at the dispersion points. Because of the readiness with which establishment is accomplished, it is probable that *H. punctorius* is now established over much of the eastern area.

MACROCENTRUS GIFUENSIS Ashm. (Fig. 22)

Order: Hymenoptera.
Family: Braconidae.
Imported from: Europe and the Orient.
Preferred host stage: Second- and third-stage larvae.

Method of parasitization: Oviparous; polyembryonic egg deposited free in body cavity of host.

Hibernation: Egg in the primary and the secondary germ stage within the body of the mature host larva.

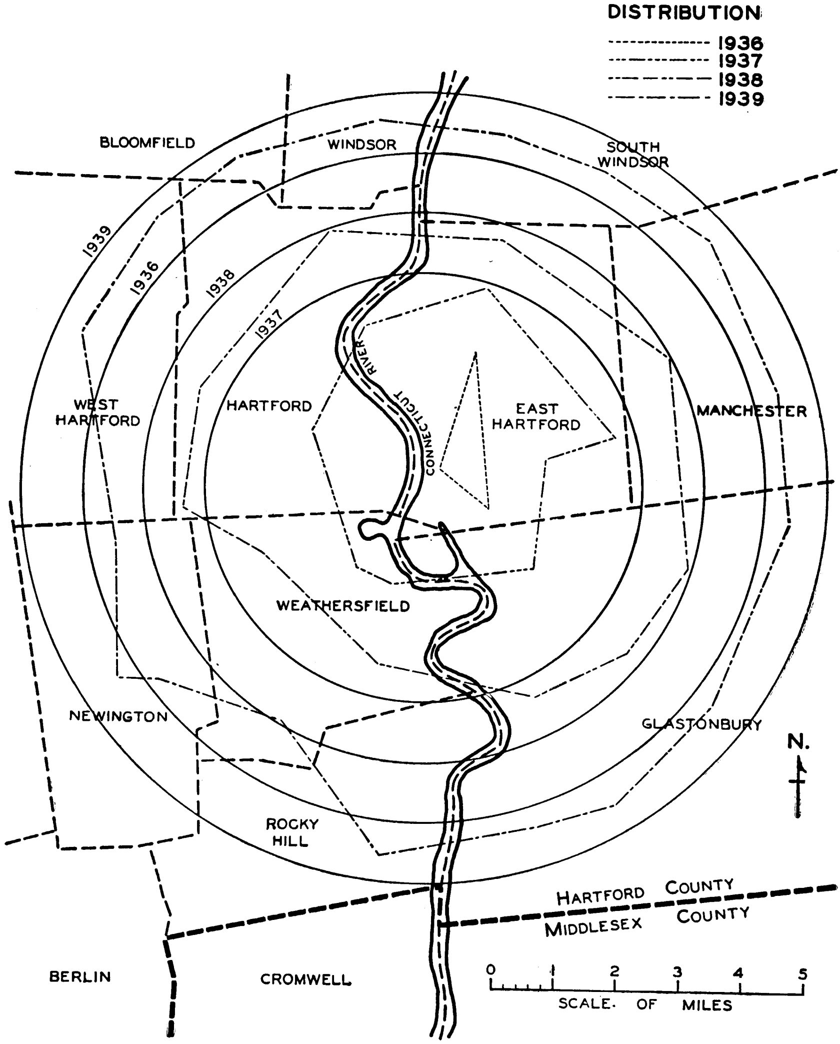

FIGURE 21.—Distribution of *Horogenes punctorius* in the vicinity of Hartford, Conn. Survey limits are indicated by solid-line concentric circles. Areas occupied by the parasite are enclosed with broken lines, as indicated in the key.

The biology and morphology of *Macrocentrus gifuensis* have been exhaustively treated by Parker (*24*), and very little has been added to our knowledge of the biology of the species through colonization activities and field-status studies in the United States.

COLONIZATION

The original supply of this polyembryonic braconid parasite for release in the United States was obtained from Europe and the Orient. All material imported from Europe originated in northern France, where the borer has but one generation a year. The oriental form, on the other hand, is found in areas having two and three generations of the host per year.

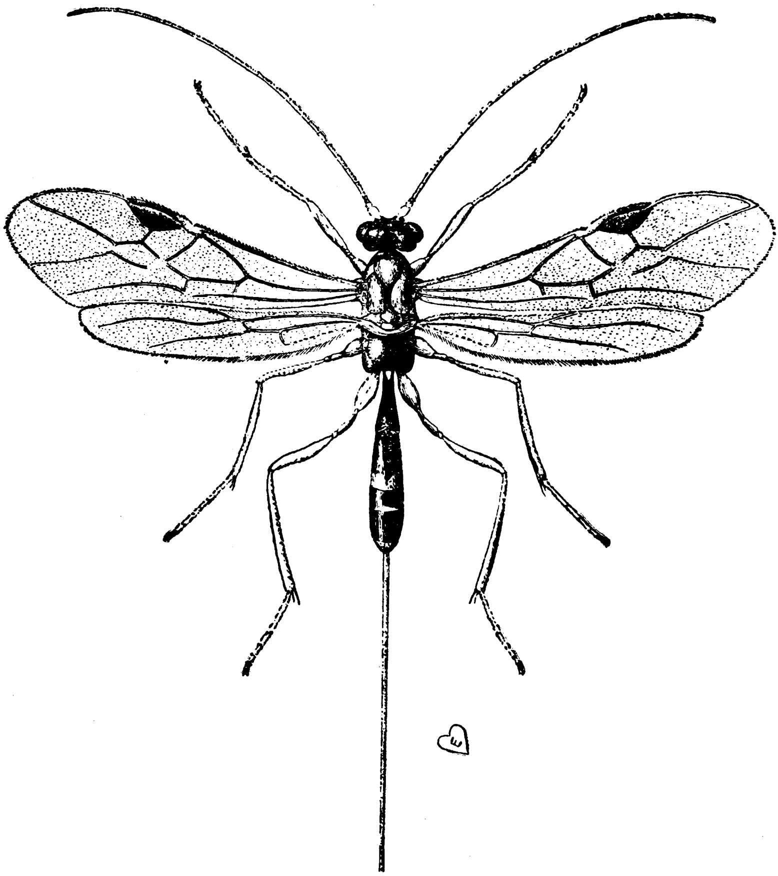

FIGURE 22.—*Macrocentrus gifuensis*, adult female. × 10.

The first adults of European origin became available for release in 1926 and were liberated in Massachusetts. In 1927 a number of colonies were released in the East and a colony of European origin was also released at Jerusalem Township, Lucas County, Ohio. In the years 1927–33 a number of colonies of European material were released annually in both the Eastern and the Lake States. In 1929 the first adults were obtained from the Orient, and material from this source continued to be received during the following 3 years. The total releases of this species in the United States are given in table 20.

FIELD STATUS

Macrocentrus gifuensis was first recovered in Perkins Township, Erie County, Ohio, in 1928 following a release that year of 8,254 adults. Initial establishment was noted at one point in 1929 and at 4 points in 1932, all in the Lake States. No evidence of permanent establishment has been observed in this area.

In the East no recovery of this species was made until 1934, when evidence of maintenance was indicated at the release point

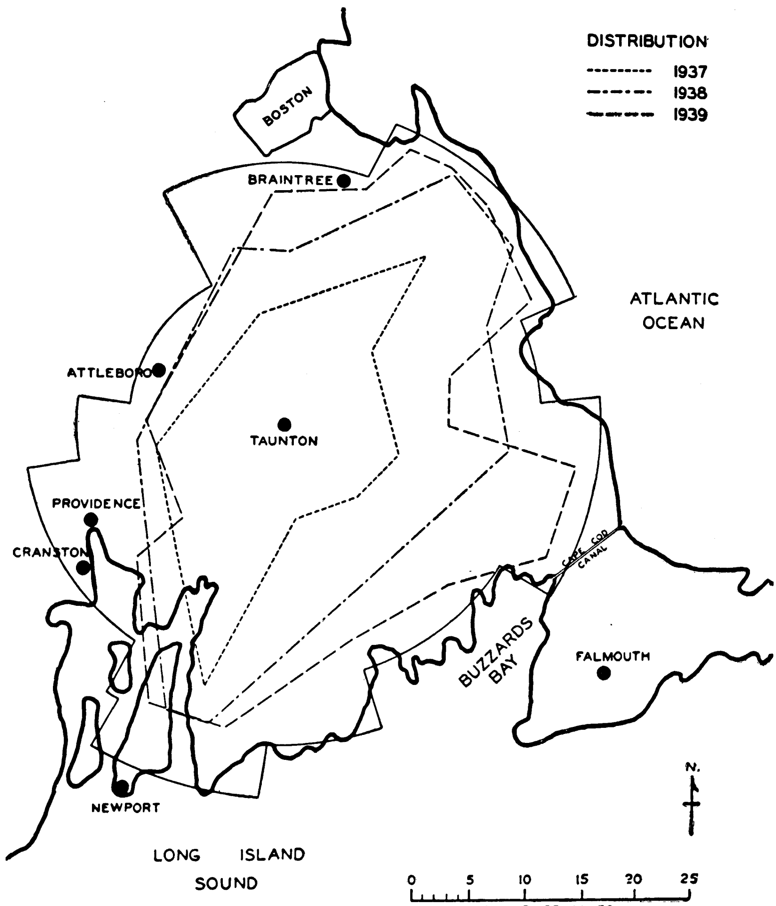

FIGURE 23.—Distribution of *Macrocentrus gifuensis* in the vicinity of Taunton, Mass., Dec. 31, 1940.

of the oriental material at Bridgewater, Mass. In the falls of 1936 and 1937 the parasite was obtained from a number of fields in the Bridgewater district. In 1937, 33 percent of the borers in one collection were parasitized by *Macrocentrus gifuensis*.

A survey of the first-generation borers in 1938 showed an average parasitization by *Macrocentrus gifuensis* of 3.9 percent in a circular area containing 490 square miles and in two of the col-

TABLE 20.—*Macrocentrus gifuensis adults released in the United States through December 31, 1940*

State and County	Township	Origin[1]	1926	1927	1928	1929	1930	1931	1932	1933	1940	Total[2]
Connecticut:												
Fairfield	Stratford	D	0	0	0	0	0	0	0	0	1,993	1,993
Hartford	E. Hartford	D	0	0	0	0	0	0	0	0	1,979	1,979
Litchfield	Litchfield	D	0	0	0	0	0	0	0	0	1,993	1,993
Middlesex	Haddam	D	0	0	0	0	0	0	0	0	1,991	1,991
New Haven	Milford	D	0	0	0	0	0	0	0	0	1,994	1,994
New London	East Lyme	E	0	0	1,806	127	0	114	139	0	0	2,186
Do	do	O	0	0	0	0	0	0	5,850	0	0	5,850
Do	Gales Ferry	D	0	0	0	0	0	0	0	0	1,997	1,997
Tolland	Tolland	D	0	0	0	0	0	0	0	0	1,995	1,995
Windham	Pomfret	D	0	0	0	0	0	0	0	0	1,992	1,992
Total			0	0	1,806	127	0	114	5,989	0	15,934	23,970
Indiana: Steuben	York	E	0	0	0	0	2,508	1,884	24	0	0	4,416
Massachusetts:												
Barnstable	Falmouth	E	0	0	3,461	0	165	262	0	0	0	3,888
Bristol	Dighton	E	0	0	0	13	0	0	0	0	0	13
Do	Swansea	E	0	0	6,820	4,115	0	0	448	0	0	11,383
Do	do	O	0	0	0	0	0	0	8,319	0	0	8,319
Essex	Danvers	D	0	0	0	0	0	0	0	0	1,953	1,953
Do	Peabody	E	0	0	0	0	0	0	244	0	0	244
Do	do	O	0	0	0	0	0	0	6,960	0	0	6,960
Do	Saugus	E	1,496	2,639	0	599	123	9	0	0	0	4,866
Franklin	Bernardston	D	0	0	0	0	0	0	0	0	1,968	1,968
Hampden	Agawam	D	0	0	0	0	0	0	0	0	1,984	1,984
Hampshire	Hadley	D	0	0	0	0	0	0	0	0	1,977	1,977
Middlesex	Arlington	E	0	3,480	3,079	16	0	0	0	0	0	6,575
Do	do	O	0	0	0	0	0	0	450	0	0	450
Do	Concord	D	0	0	0	0	0	0	0	0	1,947	1,947
Do	Malden	E	0	2,679	0	0	0	0	0	0	0	2,679
Middlesex	Medford	E	695	3,169	0	0	0	0	0	0	0	3,864

Norfolk	Quincy	E	0	3,695	6,358	0	0	0	0	0	0	10,053
Plymouth	Bridgewater	O	0	0	0	0	0	41	8,686	0	0	8,727
Suffolk	Revere	E	0	2,600	0	0	0	0	0	0	0	2,600
Worcester	Charlton	D	0	0	0	0	0	0	0	0	1,994	1,994
Total			2,191	18,262	19,718	4,743	288	312	25,107	0	11,823	82,444
Michigan:												
Lenawee	Fairfield	O	0	0	0	0	0	0	4,626	0	0	4,626
Monroe	Erie	O	0	0	0	0	0	0	21,224	0	0	21,224
Do	Monroe	E	0	0	967	3,428	1,867	236	1,455	0	0	7,953
Oakland	Oxford	E	0	0	0	0	824	0	0	0	0	824
St. Clair	Columbus	E	0	0	3,874	18	2,271	0	0	0	0	6,163
Total			0	0	4,841	3,446	4,962	236	27,305	0	0	40,790
New Jersey:												
Atlantic	Egg Harbor	D	0	0	0	0	0	0	0	0	1,996	1,996
Bergen	Paramus	D	0	0	0	0	0	0	0	0	1,996	1,996
Burlington	Burlington	D	0	0	0	0	0	0	0	0	0	3,499
Camden	Clementon	D	0	0	0	0	0	0	0	0	1,972	1,972
Gloucester	Washington	D	0	0	0	0	0	0	0	0	1,966	1,966
Mercer	do	D	0	0	0	0	0	0	0	0	1,979	1,979
Middlesex	Monroe	D	0	0	0	0	0	0	0	0	1,988	1,988
Monmouth	Atlantic	D	0	0	0	0	0	0	0	0	3,519	5,696
Ocean	Brick	D	0	0	0	0	0	0	0	0	1,981	1,981
Total			0	0	0	0	0	0	0	0	17,397	23,073
New York:												
Albany	Colonie	D	0	0	0	0	0	0	0	0	1,983	1,983
Chautauqua	Westfield	E	0	0	3,276	0	0	0	0	0	0	3,276
Columbia	Kinderhook	D	0	0	0	0	0	0	0	0	3,945	3,945
Dutchess	Hyde Park	D	0	0	0	0	0	0	0	0	1,995	1,995
Erie	Cattaraugus Indian Res.	E	0	0	0	5,946	0	0	0	0	0	5,946
Do	Lancaster	E	0	0	5,265	1	0	0	0	0	0	5,266
Greene	Coxsackie	D	0	0	0	0	0	0	0	0	1,988	1,988

TABLE 20.—*Macrocentrus gifuensis adults released in the United States through December 31, 1940—Con.*

State and County	Township	Origin[1]	1926	1927	1928	1929	1930	1931	1932	1933	1940	Total[2]
Jefferson	Adams	O	0	0	0	0	0	0	5,077	0	0	5,077
Orange	Montgomery	D	0	0	0	0	0	0	0	0	1,989	1,989
Rensselaer	E. Greenbush	D	0	0	0	0	0	0	0	0	1,986	1,986
Do	Schodack	D	0	0	0	0	0	0	0	0	1,988	1,988
Saratoga	Malta	D	0	0	0	0	0	0	0	0	1,997	1,997
Schenectady	Glenville	E	0	0	0	0	273	0	0	0	0	273
Do	do	O	0	0	0	0	80	0	0	0	0	80
Do	do	D	0	0	0	0	0	0	0	0	1,987	1,987
Suffolk	Riverhead	D	0	0	0	0	0	0	0	0	1,569	1,569
Do	Southold	E	0	0	0	0	0	0	0	17,139	0	17,139
Ulster	Kingston	D	0	0	0	0	0	0		0	0	1,902
Do	Marblehead	D	0	0	0	0	0	0		0	1,986	1,986
Total			0	0	8,541	5,947	353	0	5,077	17,139	23,413	62,372
Ohio:												
Erie	Perkins	E	0	0	8,254	0	2,739	1,432		0	0	12,425
Hancock	Marion	O	0	0	0	0	0	0	4,707	0	0	4,707
Henry	Damascus	O	0	0	0	0	2,906	0	4,211	0	0	7,117
Lake	Mentor	E	0	0	211	0	0	0	0	0	0	211
Lucas	Adams	D	0	0	0	0	0	0	0	0	3,537	3,537
Do	Jerusalem	E	0	2,053	3,060	5,104	5,028	2,174	0	0	0	17,419
Wood	Perry	E	0	0	0	0	0	0	0	73,106	0	73,106
Do	Webster	O	0	0	0	0	0	0	17,256	0	0	17,256
Total			0	2,053	11,525	5,104	10,673	3,606	26,174	73,106	3,537	135,778
Pennsylvania:												
Crawford	Wayne	E	0	0	9,006	0	0	0	0	0	0	9,006

Rhode Island:												
Kent	Coventry	D	0	0	0	0	0	0	0	0	1,993	1,993
Newport	Portsmouth	E	0	0	0	0	0	0	496	9,223	0	9,719
Do	Portsmouth	O	0	0	0	0	0	0	13,565	0	0	13,565
Providence	E. Providence	E	0	0	4,130	2,617	2,821	362	0	0	0	9,930
Do	Gloucester	D	0	0	0	0	0	0	0	0	1,989	1,989
Washington	Richmond	D	0	0	0	0	0	0	0	0	1,986	1,986
Total			0	0	4,130	2,617	2,821	362	14,061	9,223	5,968	39,182
Total, United States			2,191	20,315	59,567	21,984	21,605	6,514	103,737	99,468	78,072	421,031

[1] D, Domestic; E, Europe; O, the Orient.

[2] This total includes 2,489 adults liberated in Burlington Township; Burlington County, N. J., in 1938, and in 1939, 1,010 adults in the same township, 2,177 adults in Atlantic Township, Monmouth County, N. J., and 1,902 adults in Kingston Township, Ulster County, N. Y.

lections over 35 percent of the borers were parasitized. In the fall of that year, in a circular area of 1,963 square miles, 8 percent of the borers were parasitized by *M. gifuensis*. In the central 500-square-mile portion of this area parasitization had increased to an average 10.8 percent. Forty-seven of the 100 collections made in the Taunton area in the fall of 1938 produced *M. gifuensis*, and in these 47 collections 15 showed a parasitization of over 20 percent by this species. The maximum parasitization by *M. gifuensis* for any collection was 56.3 percent. The area of highest concentration was a district within 10 miles of the release point at East Bridgewater, Mass. From the 9,731 host larvae observed, 779 cocoon clusters were produced and 15,055 adults obtained. Figure 23 shows the area in the vicinity of Taunton, Mass., from which this parasite was recovered in the fall surveys of 1937, 1938, and 1939.

In 1939 a survey to determine the status of parasites on the first generation of the borer in a 500-square-mile area in the vicinity of Bridgewater, Mass., revealed a parasitization by *Macrocentrus gifuensis* of 12.1 percent, which was the highest recorded for any parasite and comprised 46 percent of the total by all species. These data indicated that *M. gifuensis* was continuing to increase in effectiveness, since the 12.1 percent recorded in the summer of 1939 is comparable to the 3.9 percent obtained in a similar survey in the same area of the first-generation borers in the summer of 1938. Enough adults were obtained in 1940 from parasitized borers in a special collection made in the vicinity of Bridgewater to permit the release elsewhere of 39 colonies, totaling over 78,000 individuals.

No morphological characters have been found to differentiate the oriental from the European strain of *Macrocentrus gifuensis*. However, certain differences in their reactions point to the possibility of distinct biological strains. As stated above, the oriental form is abundant in an area having three generations of the borer per year, and is present in 2-generation areas and in transitional zones in the Orient. It either does not occur or is extremely scarce in the Orient in regions where the host has one generation each year. In Europe the opposite situation obtains, since in that country the parasite is found only in an area where the host has but one generation a year. In the eastern area of borer infestation in the United States by far the greatest number of releases were of adults of European origin, yet the only locality in which maintenance of the species prevails is in the vicinity of the liberation point of a colony of adults from the Orient.

In the Lake States the species was recovered at six localities, each recovery being made in the year of a release in that locality. The details of these recoveries were as follows:

Perkins, Erie County, Ohio: Colonized in 1928 with European stock. One parasitized larva was found in a collection of 1,828 corn borers. Only 935 of these borers were taken near the field of release, and from these the *Macrocentrus gifuensis* was recovered.

Cattaraugus Indian Reservation, N. Y.: Colonized in 1929 with European stock. One parasitized larva was obtained from a col-

lection of 1,333 borers. A parasite was also obtained from a collection of 18 borers taken from the field of liberation.

Fairfield, Lenawee County, Mich.: Colonized in 1932 with oriental stock. One parasitized larva was found in a collection of 3,187 borers. The parasite cluster was recovered from 400 host larvae taken as cocoons in October at the release field.

Monroe, Erie County, Mich.: Colonized in 1932 with oriental stock. Three parasitized larvae were found in a collection of 1,501 borers. Parasites were recovered from 100 host larvae taken at the release point. Two clusters of parasite cocoons were collected in October.

Webster, Wood County, Ohio: Colonized in 1932 with oriental stock. Two parasitized larvae were found in a collection of 3,394 borers. Parasite clusters were recovered from 400 host larvae taken at the release point. Parasitized larvae were in cocoons in October.

Adams, Jefferson County, New York: Colonized in 1932 with oriental stock. From a collection of 3,129 borers 24 parasitized larvae were found. The parasites were all recovered from 400 borers taken from release fields. At the time of collection in October clusters of parasite cocoons had been produced from 5 of the 24 parasitized larvae.

No initial establishment was accomplished where less than 1,800 adults were released at one time. Disregarding all locations where less than this number were released per day, 14 colonies of European material and only 6 of oriental stock remained. Nevertheless, 4 of the 6 recovery points were oriental colony sites. Of 32 borers parasitized by *Macrocentrus gifuensis,* 30 had been attacked by adults of oriental origin.

It was noted also that all the parasites of European origin passed the winter normally, that is, within the host larva; whereas at all of the oriental-colony sites some or all of the larvae had emerged and spun cocoons prior to the time of collection. This phenomenon of fall emergence has been noted to a slight extent at the oriental colony site at Bridgewater, Mass. While exhibiting a partial lack of adaptation to the environment, this emergence also demonstrated that the diapause is not obligatory with the oriental strain, although it may be with adults from Europe.

ALTERNATE HOSTS

Parker (*24*), in discussing the host relations of *Macrocentrus gifuensis,* states: "So far as is known it has not been reared from any host other than *Pyrausta nubilalis.* It is possible, however, that *M. gifuensis* has often been misidentified as *M. abdominalis* and that, consequently, some of the biological and descriptive data in publications on *M. abdominalis* pertain in reality to *M. gifuensis.*"

In 1932 three larvae of the lotus borer (*Pyrausta penitalis* (Grote)), collected from lotus near the Erie Township, Monroe County, Mich., release point, produced adults of *Macrocentrus gifuensis.* This is the only record of reproduction of the species in the United States on hosts other than *Pyrausta nubilalis.* No laboratory experiments have been conducted to provide data on host relationship with this species.

RÉSUMÉ OF THE STATUS OF MACROCENTRUS GIFUENSIS

In 1941 this polyembryonic braconid larval parasite was established in the United States only in southeastern New England. However, it exhibited a population density greater than that of any other parasite, and the average parasitization produced compares favorably with that of any of the introduced parasites in other parts of the borer-infested area.

Clark (*11*) in discussing *Macrocentrus gifuensis*, says that it "is one of the most important parasites of the corn borer in the Orient." Concerning its status in Europe, Parker (*24*) writes: "The percentage of parasitism in the weed (Artemesia) areas of the Armorican zone of France has, however, maintained itself around 30 percent for several years; it is thus seen that this parasite is a factor which cannot be neglected in the fight against the corn borer."

Its estimable position, therefore, in the countries of its origin, together with the parasitization it has accomplished at Bridgewater, Mass., indicate the possibilities of this parasite. Collections of borers, chiefly parasitized by *Macrocentrus gifuensis*, are being made in southeastern Massachusetts for the purpose of providing material for further distribution in the Eastern States. No further colonization is contemplated where only the single-generation strain of the borer occurs.

CHELONUS ANNULIPES Wesm. (Fig. 24)

Order: Hymenoptera.
Family: Braconidae.
Imported from: Italy.
Preferred host stage for oviposition: The egg.
Method of parasitization: Oviparous; egg deposited subcutaneously in host egg.
Hiberation: First-instar larva free in body cavity of fourth-instar host larva.

Chelonus annulipes Wesm. is the only imported parasite of the European corn borer that attacks the host in the egg stage. Its biology and some phases of its embryology, physiology, and the technique used in its rearing have been reported by various authors (*6, 7, 40, 44*). Prior to its introduction into the United States the parasite was recorded onl'' from northern Italy.

COLONIZATION

The first importations of this species were made in the summer of 1929, when parasite cocoons were shipped under refrigeration. The following winter, and in subsequent years, the introduction was accomplished by shipping the host borers containing first-instar parasite larvae. A considerable number of the earlier introduced adults were retained for laboratory study, but enough were available to make possible some releases in eastern Massachusetts. It was found practical during the later years of importation to differentiate by size and appearance between parasitized and nonparasitized borers.

A suitable technique for rearing this species in the laboratory on the Mediterranean flour moth (*Ephestia kuehniella* Zell.) was later developed by Bradley (*6*). By this method the number of adults available from foreign importation were considerably augmented by laboratory-reared material. In 1938 over 130,000 and in 1939 over 75,000 adults were produced by using *E. kuehniella* as the rearing host.

The first colonies were released in the Lake States area in 1930. In 1937 the Entomological Branch of the Canadian Department of Agriculture supplied a sufficient number of adults from laboratory-reared material for releases at two colony sites on the Eastern Shore of Virginia. Table 21 shows the numbers of *Chelonus annulipes* adults released each year at the various liberation points.

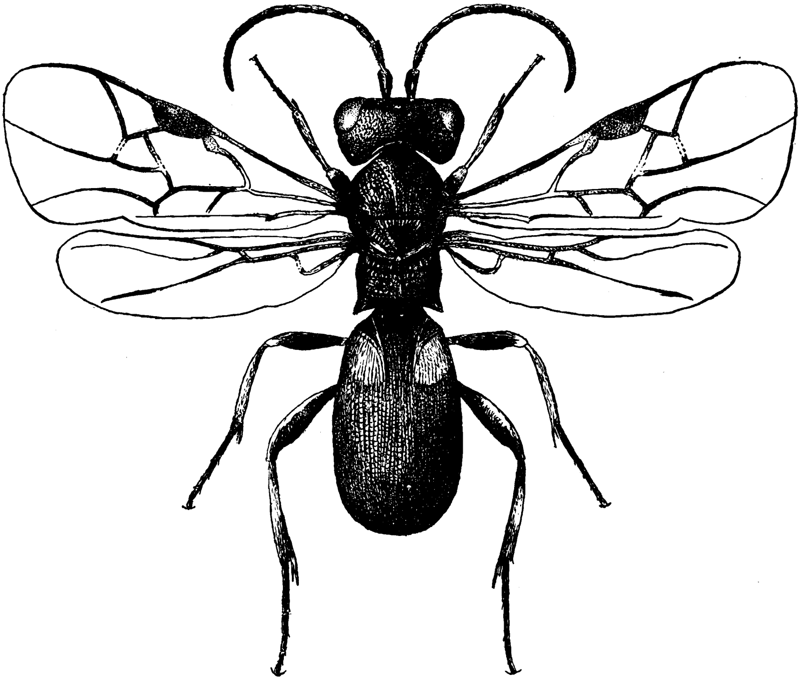

FIGURE 24.—*Chelonus annulipes*, adult female. × 10.

An examination of all available data relative to the geographical distribution of *Chelonus annulipes* indicates that its environmental requirements are extremely exacting and not readily determinable. Although it has been reared from several countries of Europe, it has been found (as a parasite of the European corn borer) by personnel of the United States Department of Agriculture, only in the northern part of Italy, and is recorded as being very unevenly distributed in that region. It was collected in numbers at St. Georgio di Nogaro, Italy, but was not found in the vicinity of Venice, less than 50 miles distant. Between areas where the parasite was plentiful and areas where it was rare, monthly temperatures and annual rainfall varied little.

TABLE 21.—*Numbers of Chelonus annulipes adults released in the United States through December 31, 1940*

State and County	Township	Origin[1]	1930	1931	1932	1933	1934	1937	1938	1939	1940	Total[2]
Connecticut:[3]												
Fairfield	Fairfield	B	0	0	0	0	0	0	988	0	0	988
Do	Southport	B	0	0	0	0	0	0	0	996	0	996
Do	Stratford	B	0	0	0	0	0	0	0	1,992	0	1,992
Hartford	Berlin	B	0	0	0	0	0	0	0	994	0	994
Do	Cromwell	B	0	0	0	0	0	0	0	991	0	991
Do	E. Granby	B	0	0	0	0	0	0	0	995	0	995
Do	E. Hartford	B	0	0	0	0	0	0	0	1,000	0	1,000
Do	do	E	0	0	0	0	242	593	0	0	0	835
Do	E. Windsor	B	0	0	0	0	0	0	0	966	0	996
Do	Enfield	B	0	0	0	0	0	0	0	2,984	0	2,984
Do	Farmington	B	0	0	0	0	0	0	0	991	0	991
Do	Glastonbury	B	0	0	0	0	0	0	0	1,984	0	1,984
Do	Manchester	B	0	0	0	0	0	0	0	1,000	0	1,000
Do	Rocky Hill	B	0	0	0	0	0	0	0	995	0	995
Do	Southington	B	0	0	0	0	0	0	0	986	0	986
Do	S. Windsor	B	0	0	0	0	0	0	0	1,993	0	1,993
Do	Suffield	B	0	0	0	0	0	0	0	2,990	0	2,990
Do	Weathersfield	B	0	0	0	0	0	0	0	997	0	997
Do	Windsor	B	0	0	0	0	0	0	0	1,995	0	1,995
Middlesex	Durham	B	0	0	0	0	0	0	0	1,986	0	1,986
Do	Guildford	B	0	0	0	0	0	0	0	986	0	986
Do	Haddam	B	0	0	0	0	0	0	994	0	0	994
Do	Middletown	B	0	0	0	0	0	0	0	1,992	0	1,992
New Haven	Branford	B	0	0	0	0	0	0	0	1,992	0	1,992
Do	Cheshire	B	0	0	0	0	0	0	0	991	0	991
Do	E. Haven	B	0	0	0	0	0	0	0	992	0	992
Do	Hamden	B	0	0	0	0	0	0	0	994	0	994
Do	Meriden	B	0	0	0	0	0	0	0	1,983	0	1,983
Do	Milford	B	0	0	0	0	0	0	0	988	0	988
Do	do	B	0	0	0	0	0	0	0	987	0	987
Do	New Haven	E	0	0	0	0	0	590	0	0	0	590
Do	N. Branford	B	0	0	0	0	0	0	0	996	0	996
Do	N. Haven	B	0	0	0	0	0	0	0	2,987	0	2,987
Do		B	0	0	0	0	0	0	0	992	0	992

New Haven	Orange	B	0	0	0	0	0	0	0	994	0	994
Do	Wallingford	B	0	0	0	0	0	0	0	2,977	0	2,977
New London	E. Lyme	B	0	16	0	0	0	0	989	0	0	1,226
Do	do	E	0	18	1,603	0	0	0	0	0	0	1,748
Tolland	Ellington	B	0	0	0	0	0	0	0	1,000	0	1,000
Do	Sommers	B	0	0	0	0	0	0	0	1,000	0	1,000
Total			0	34	1,603	0	242	1,183	2,971	47,724	0	54,105
Indiana:												
Adams	Union	B	0	0	0	0	0	0	0	1,246	0	1,246
Allen	Jackson	B	0	0	0	0	0	0	0	1,238	0	1,238
De Kalb	Butler	B	0	0	0	0	0	0	0	995	0	995
Noble	Washington	B	0	0	0	0	0	0	0	997	0	997
Steuben	York	E	168	0	2,091	0	0	0	0	0	0	2,259
Total			168	0	2,091	0	0	0	0	4,476	0	6,735
Maryland: Worcester	Newark	B	0	0	0	0	0	0	1,981	0	0	1,981
Massachusetts:[4]												
Barnstable	Falmouth	B	31	582	0	0	0	0	0	0	0	613
Do	do	E	93	0	0	0	0	0	0	0	0	93
Bristol	Dighton	E	0	0	0	0	0	0	0	0	0	90
Do	Swansea	E	0	0	2,526	0	0	0	0	0	0	2,526
Do	do	B	0	0	309	0	0	0	0	0	0	309
Essex	Haverhill	B	0	0	0	0	0	0	971	0	0	971
Do	Peabody	B	0	0	28	0	0	0	0	0	0	28
Do	do	E	0	0	612	0	0	0	0	0	0	612
Do	Saugus	B	252	603	0	0	0	0	0	0	0	855
Do	do	E	11	86	0	0	0	0	0	0	0	97
Franklin	Bernardston	B	0	0	0	0	0	0	960	0	0	960
Hamden	Agawam	B	0	0	0	0	0	0	976	0	0	976
Hampshire	Hadley	B	0	0	0	0	0	0	966	0	0	966
Middlesex	Arlington	E	0	0	0	0	0	0	0	0	0	614
Do	Concord	B	0	0	74	0	0	0	0	0	0	74
Do	do	E	0	0	2,937	0	34	0	0	0	0	2,971
Do	Medford	B	0	0	229	0	0	0	0	0	0	229

TABLE 21.—*Chelonus annulipes adults released in the United States through December 31, 1940—Con.*

State and County	Township	Origin[1]	1930	1931	1932	1933	1934	1937	1938	1939	1940	Total[2]
Massachusetts—Cont'd.												
Middlesex												
Do	Sundbury	B	0	0	0	0	0	0	982	0	0	982
Norfolk	Norfolk	B	0	0	0	0	0	0	968	0	0	968
Plymouth	Bridgewater	B	0	0	93	0	0	0	0	0	0	93
Worcester	Charlton	B	0	0	0	0	0	0	983	0	0	983
Total			387	1,271	6,808	0	34	0	6,806	0	0	16,010
Michigan:												
Lenawee	Fairfield	E	0	0	0	1,163	0	0	0	0	0	1,163
Monroe	Erie	E	0	0	3,514	0	0	0	0	0	0	3,514
Do	Monroe	E	0	309	0	0	0	0	0	0	0	309
Washtenaw	Augusta	E	0	0	0	0	600	0	0	0	0	600
Wayne	Livonia	E	0	0	0	0	777	0	0	0	0	777
Total			0	309	3,514	1,163	1,377	0	0	0	0	6,363
New Jersey:												
Atlantic	Egg Harbor	B	0	0	0	0	0	0	991	0	0	991
Bergen	Paramus	B	0	0	0	0	0	0	997	0	0	997
Burlington	Burlington	B	0	0	0	0	0	0	2,000	0	0	2,000
Mercer	Washington	B	0	0	0	0	0	0	996	0	0	996
Middlesex	Monroe	B	0	0	0	0	0	0	1,000	0	0	1,000
Monmouth	Atlantic	E	0	0	0	0	0	450	0	0	0	450
Do	do	D	0	0	0	0	0	0	0	0	1,251	1,251
Ocean	Brick	B	0	0	0	0	0	0	996	0	0	996
Total			0	0	0	0	0	450	6,980	0	1,251	8,681
New York:												
Albany	Bethlehem	B	0	0	0	0	0	0	0	0	6,968	6,968

Do	Coeymans	B	0	0	0	0	0	0	0	999	1,993	2,992
Do	Colonie	B	0	0	0	0	0	0	0	0	6,953	6,953
Do	New Scotland	B	0	0	0	0	0	0	0	0	998	998
Columbia	Claverack	B	0	0	0	0	0	0	0	0	1,993	1,993
Do	Clermont	B	0	0	0	0	0	0	0	0	2,742	2,742
Do	Germantown	B	0	0	0	0	0	0	0	994	999	1,993
Do	Ghent	B	0	0	0	0	0	0	0	0	1,999	1,999
Do	Greenport	B	0	0	0	0	0	0	0	997	3,493	4,490
Do	Kinderhook	B	0	0	0	0	0	0	0	1,982	7,945	9,927
Do	Livingston	B	0	0	0	0	0	0	0	989	2,245	3,234
Do	Stockport	B	0	0	0	0	0	0	0	996	1,999	2,995
Do	Stuyvesant	B	0	0	0	0	0	0	0	0	8,976	8,976
Dutchess	Clinton	B	0	0	0	0	0	0	0	993	989	1,982
Do	E. Fishkill	B	0	0	0	0	0	0	0	0	748	748
Do	Fishkill	B	0	0	0	0	0	0	0	0	3,983	3,983
Do	Hyde Park	B	0	0	0	0	0	0	0	990	4,979	5,969
Do	LaGrange	B	0	0	0	0	0	0	0	0	1,498	1,498
Do	Poughkeepsie	B	0	0	0	0	0	0	0	983	3,722	4,705
Do	Red Hook	B	0	0	0	0	0	0	0	1,965	1,746	3,711
Do	Rhinebeck	B	0	0	0	0	0	0	0	987	992	1,979
Do	Wappinger	B	0	0	0	0	0	0	0	0	1,743	1,743
Greene	Athens	B	0	0	0	0	0	0	0	990	0	990
Do	Catskill	B	0	0	0	0	0	0	0	991	4,840	5,831
Do	Coxsackie	B	0	0	0	0	0	0	0	998	2,993	3,991
Do	New Baltimore	B	0	0	0	0	0	0	0	997	998	1,995
Jefferson	Adams	E	0	0	1,482	0	0	0	0	0	0	1,482
Monroe	Hamlin	E	0	0	0	0	424	0	0	0	0	424
Ontario	Phelps	E	0	0	0	0	189	0	0	0	0	189
Orange	Montgomery	B	0	0	0	0	0	0	0	0	1,498	1,498
Oswego	Scriba	E	0	0	0	0	459	0	0	0	0	459
Rensselaer	E. Greenbush	B	0	0	0	0	0	0	0	0	2,985	2,985
Do	Schodack	B	0	0	0	0	0	0	0	0	3,991	3,991
Schenectady	Glenville	F	599	0	0	0	0	0	0	0	0	599
Suffolk	Riverhead	B	0	0	0	0	0	0	999	0	0	999
Do	Southold	B	0	0	0	1,080	0	0	0	0	0	1,080
Do	do	E	0	0	0	550	0	0	0	0	0	550
Ulster	Esopus	B	0	0	0	0	0	0	0	2,995	2,463	5,458
Do	Hurley	B	0	0	0	0	0	0	0	0	1,733	1,733
Do	Kingston	B	0	0	0	0	0	0	0	995	1,234	2,229
Do	Lloyd	B	0	0	0	0	0	0	0	0	2,444	2,444

TABLE 21.—*Chelonus annulipes adults released in the United States through December 31, 1940—Con.*

State and County	Township	Origin[1]	1930	1931	1932	1933	1934	1937	1938	1939	1940	Total[2]
New York—Cont'd.												
Ulster	Marbletown	B	0	0	0	0	0	0	0	0	1,995	1,995
Do	New Paltz	B	0	0	0	0	0	0	0	0	748	748
Do	Plattekill	B	0	0	0	0	0	0	0	0	997	997
Do	Rosendale	B	0	0	0	0	0	0	0	0	746	746
Do	Saugerties	B	0	0	0	0	0	0	0	1,985	4,930	6,915
Do	Ulster	B	0	0	0	0	0	0	0	0	4,915	4,915
Total			599	0	1,482	1,630	1,072	0	999	22,826	109,213	137,821
Ohio:												
Allen	Shawnee	E	0	0	0	0	592	0	0	0	0	592
Auglaize	Washington	E	0	0	0	0	685	0	0	0	0	685
Erie	Berlin	B	0	0	0	0	0	0	0	0	2,247	2,247
Do	Perkins	E	0	0	0	0	595	0	0	0	0	595
Fulton	German	E	0	0	0	0	604	0	0	0	0	604
Hancock	Marian	E	0	0	1,380	0	0	0	0	0	0	1,380
Hardin	Liberty	E	0	0	0	0	570	0	0	0	0	570
Henry	Damascus	E	0	358	5,741	0	0	0	0	0	0	6,099
Lucas	Adams	B	0	0	0	0	0	0	1,538	0	0	1,538
Do	Jerusalem	E	4,497	0	0	0	0	0	0	0	0	4,497
Ottawa	Salem	E	0	0	0	0	508	0	0	0	0	508
Paulding	Brown	E	0	0	0	0	723	0	0	0	0	723
Putnam	Jennings	E	0	0	0	0	597	0	0	0	0	597
Sandusky	Ballville	E	0	0	0	0	721	0	0	0	0	721
Seneca	Seneca	E	0	0	0	0	598	0	0	0	0	598
Williams	Madison	E	0	0	0	0	47	0	0	0	0	47
Wood	Perry	E	0	0	0	951	0	0	0	0	0	951
Total			4,497	358	7,121	951	6,240	0	1,538	0	2,247	22,952

Rhode Island:												
Newport	Portsmouth	B	0	0	8	262	0	0	0	0	0	270
Do	do	E	0	0	713	1,048	0	0	0	0	0	1,761
Providence	E.Providence	B	1,733	3,071	0	0	0	0	0	0	0	4,804
Do	do	E	682	6	0	0	0	0	0	0	0	688
Total			2,415	3,077	721	1,310	0	0	0	0	0	7,523
Vermont:												
Bennington	Arlington	B	0	0	0	0	0	0	998	0	0	998
Chittenden	Essex	B	0	0	0	0	0	0	996	0	0	996
Grande Isle	Grande Isle	B	0	0	0	0	0	0	995	0	0	995
Rutland	Poultney	B	0	0	0	0	0	0	1,000	0	0	1,000
Washington	Middlesex	B	0	0	0	0	0	0	997	0	0	997
Windham	Jamaica	B	0	0	0	0	0	0	999	0	0	999
Windsor	Bridgewater	B	0	0	0	0	0	0	997	0	0	997
Total			0	0	0	0	0	0	6,982	0	0	6,982
Virginia:[5]												
Accomac	Lee	B[6]	0	0	0	0	0	8,061	0	0	0	10,166
Northampton	Franktown	B[6]	0	0	0	0	0	611	0	0	0	611
Total			0	0	0	0	0	8,672	0	0	0	10,777
Total, United States			8,066	5,049	23,340	5,054	8,965	10,305	28,257	75,026	112,711	279,930

[1] B, Bred in the laboratory; D, Domestic; E, European.

[2] The totals in this column include the numbers given in the footnotes to this table.

[3] In 1929, 221 parasites bred in the laboratory and 127 from Europe were released in East Lyme Township, New London County.

[4] In 1929, 90 parasites from Europe were released in Dighton Township, Bristol County and 614, also from Europe, were released in Arlington Township, Middlesex County.

[5] In 1936, 2,105 parasites bred in the laboratory in Canada were released in Lee Township, Accomac County.

[6] Bred in the laboratory in Canada.

In the United States, although the parasite had been colonized over most of the area infested by the corn borer, the release points were comparatively far apart and, prior to 1939, many of the 62 colony points at which releases had been made (28 in the western area of infestation and 34 in the eastern), had not been examined, owing to their recent establishment. However, of the many points where the status of parasites was investigated in 1938, recovery was obtained only in southeastern New England. Here parasitization compared favorably with that accomplished by other corn borer parasites; yet, at the actual points of release, within 10 miles of the center of the area in which the parasite is now well established, no *Chelonus annulipes* were recovered in the three years prior to 1940.

The foregoing observations indicate that this braconid is a parasite that can exist only in a more or less restricted ecological island, producing effective parasitization in the central portion and diminishing in numbers as the less favorable periphery is approached. Apparently the success of colonization depends largely on whether the release was made in one of these ecological islands, and the chances for successful establishment may diminish as the distance from the more favorable part of the island increases. Once established, the parasite seems capable of spreading to some extent. It appeared impossible, with limited knowledge of the restricting factors, to select colony sites optimum for this parasite's establishment. To minimize this limitation and to establish the practical utility of close colonization for rapid increase of parasite populations, rather than to depend on natural dispersion from widely separated release points, it was proposed to release *Chelonus annulipes* over a well-infested area in colonies so closely spaced that one or more would probably be located near the center of a favorable ecological island.

Two areas were selected for this study: (1) A strip 16 miles wide, extending from the Massachusetts-Connecticut line south along the Connecticut River to Hartford, then southwesterly along the Quinnipaac River to New Haven; (2) an area 10 miles wide, extending from New York City northward along both sides of the Hudson River as far as Troy.

In the area selected for colonization in Connecticut, 48 colonies averaging close to 1,000 adults per colony and spaced about 4 miles apart, were released in 1939 at a time for good synchronization with large numbers of host eggs. Twenty-three colonies of similar size were released that year in the Hudson River Valley. Field examinations made at the time of these releases showed that, while host eggs were still present in small numbers in the fields, the releases in New York were later than the optimum time for good synchronization. The lower Hudson River Valley was recolonized in 1940 when 110 colonies, totaling 109,213 adults of *Chelonus annulipes*, were released in this territory. Excellent synchronization of parasite releases with presence of host eggs was attained.

To test the effect of climatic changes after 1932, and the influence that might result from the prevalence of a 2-generation

strain of the borer in the Lake States, one colony of *Chelonus annulipes* was released in Adams Township, Lucas County, Ohio, in 1938 and four in northwestern Indiana in 1939.

FIELD STATUS

As shown previously under the general discussion on colonization, proper synchronization of releases with the presence of preferred host stages of the borer usually resulted in good initial establishment. In the Lake States area, however, the species became established at but one locality, Jerusalem Township, Lucas County, Ohio, whence for a number of years after the last release, *Chelonus annulipes* appeared in borer collections. It has not been recovered at that locality since 1934. At the release location in Adams Township, Lucas County, founded in 1938, an increase in population of this parasite was indicated by collections made in the fall of 1939; however, the parasite failed to appear in the 1940 collections.

In the fall of 1932 in the Eastern States one specimen was taken 2½ miles east of the release point at East Providence, R. I. In the spring of 1933 another specimen was recovered near the Bridgewater, Mass., release point. In the fall of 1934 several specimens were collected near Dighton, Mass., and collections made in the fall of 1935 showed that the parasite was maintaining itself in encouraging numbers at that point. Continued increase in numbers was shown by the 1936 survey and in 1937 the parasite was recovered from an area of approximately 75 square miles. In that year in three collections made near the central district of the surveyed area parasitization by *Chelonus annulipes* was 13.0, 15.2, and 24 percent.

Although the percentage of parasitization by *Chelonus annulipes* did not increase in 1938, recoveries were made over a larger territory. The parasite concentration district remained the same as in 1937 and covered an area of approximately 75 square miles, centering at Berkley, Mass. In the fall of 1937 two outlying localities (Abington and South Wareham), where this parasite was present 10 to 15 miles from the center of its establishment, were noted. In the fall of 1938 the presence of *C. annulipes* at nearly the same two localities (West Bridgewater and South Wareham) was confirmed. The parasite was also recovered at East Middleborough, Mass., from a collection made between these outlying points. A 10-mile-southward extension of the parasite's habitat was disclosed by its recovery from a collection made just south of Fall River. It is estimated that *C. annulipes* was present at the close of 1938 over an area of 292 square miles in southeastern Massachusetts, an increase of 142 square miles in its known habitat having been established as a result of the fall survey of 1938.

RÉSUMÉ OF THE STATUS OF CHELONUS ANNULIPES

The last surveys made in the East showed this braconid to be on a maintenance basis at only one locality, namely, that centering at Taunton, Mass.

TABLE 22.—*Numbers of Zaleptopygus flavo-orbitalis adults released in the United States, through December 31, 1940*

State and County	Township	1929	1930	1931	1932	1933	1934	1935	1936	Total
Connecticut:										
Hartford	East Hartford	0	0	0	0	0	76	172	0	248
New Haven	Milford	0	0	0	0	0	0	599	0	599
New London	East Lyme	25	93	203	315	0	0	0	0	636
Total		25	93	203	315	0	76	771	0	1,483
Massachusetts:										
Bristol	Swansea	0	0	0	1,668	0	0	0	0	1,668
Essex	Peabody	0	0	0	705	0	0	0	0	705
Essex	Saugus	220	371	18	0	0	0	0	0	609
Middlesex	Arlington	0	2	0	15	0	0	0	0	17
Do	Concord	0	0	0	0	0	22	0	0	22
Do	Medford	0	0	0	593	0	0	0	0	593
Plymouth	Bridgewater	0	0	1,660	1,488	0	0	0	0	3,148
Total		220	373	1,678	4,469	0	22	0	0	6,762
New Jersey:										
Ocean	Berkeley	0	0	0	0	0	0	0	599	599
Monmouth	Atlantic	0	0	0	0	0	0	593	0	593
Total		0	0	0	0	0	0	593	599	1,192
New York:										
Schenectady	Glenville	0	276	0	0	0	0	0	0	276
Suffolk	Riverhead	0	0	0	0	0	0	600	0	600
Do	Southold	0	0	0	0	233	0	0	0	233
Total		0	276	0	0	233	0	600	0	1,109

Ohio:										
Henry	Damascus	0	0	0	2,824	0	0	0	0	2,824
Lucas	Jerusalem	0	0	0	2,321	0	0	0	0	2,321
Total		0	0	0	5,145	0	0	0	0	5,145
Rhode Island:										
Newport	Portsmouth	0	0	0	522	360	0	0	0	882
Providence	E. Providence	116	16	0	0	0	0	0	0	132
Total		116	16	0	522	360	0	0	0	1,014
Virginia:										
Accomac	Lee	0	0	0	0	0	0	600	1,191	1,791
Northampton	Franktown	0	0	0	0	0	0	0	1,180	1,180
Total		0	0	0	0	0	0	600	2,371	2,971
Total, United States		361	758	1,881	10,451	593	98	2,564	2,970	19,676

In the Lake States area strong initial establishment was obtained in Adams Township, Lucas County, Ohio, where releases were made in 1938 to test the effect on the parasites of the host's tendency to produce a greater proportion of 2-generation individuals than formerly. The collections made in 1939 at this point indicated a considerable increase in numbers of the parasite.

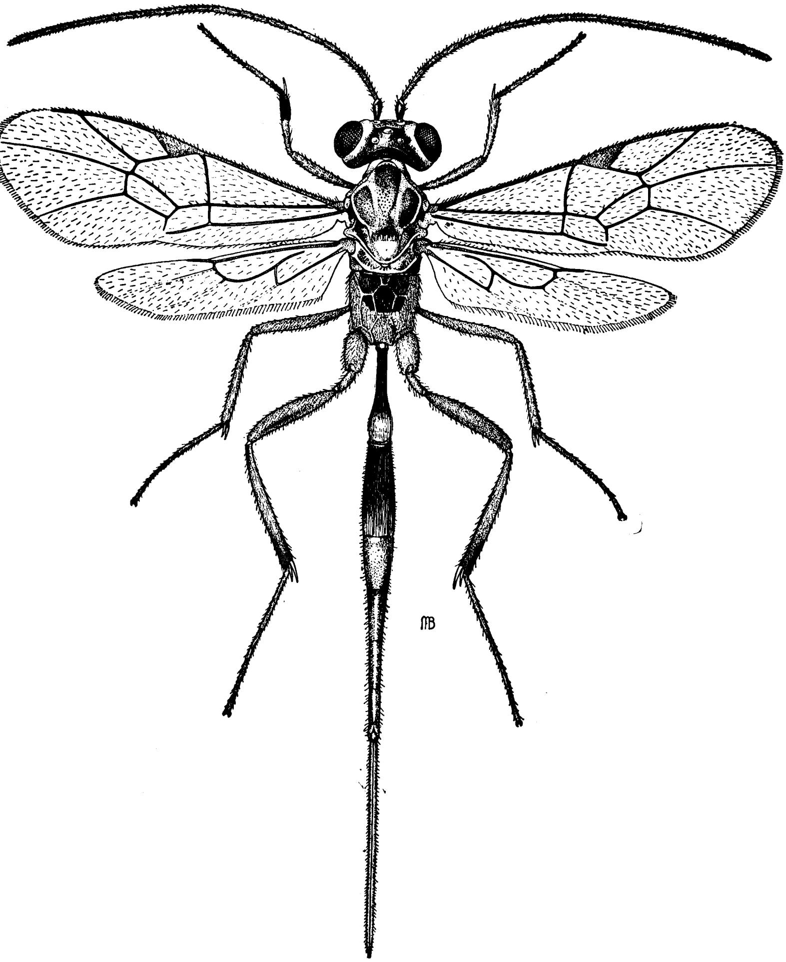

FIGURE 25.—*Zaleptopygus flavo-orbitalis*, adult female. × 10.

ZALEPTOPYGUS FLAVO-ORBITALIS (Cam.) (Fig. 25)

Order: Hymenoptera.
Family: Ichneumonidae.
Preferred host stage: Third- and fourth-instar larvae.
Imported from: Japan.
Method of parasitization: Egg deposited free in body cavity of host.
Hibernation: As a first-instar larva within the host.

Zaleptopygus flavo-orbitalis is the only hymenopterous parasite imported from the Orient and released in the United States that has not been found also in Europe. Its biology as a parasite of the European corn borer has been studied by Bradley and Burgess (*8*).

COLONIZATION

The first importations of this species were made in 1929, and releases in the Eastern and Lake States were continued for a number of years. Table 22 presents colonization data for the species.

FIELD STATUS

Subsequent to the release of *Zaleptopygus flavo-orbitalis* in the Lake States area, limited field observations were made relative to its seasonal history and environmental reactions in Jerusalem Township, Lucas County, Ohio, where initial establishment was obtained in 1932. Dissections of host larvae that had diapaused in the field at this location showed a mortality of the parasite larvae of 73.9 percent. This mortality was thought to be due to cold, and such a demonstrated weakness was at that time deemed largely responsible for the failure of the species to attain a maintenance status at any point in the infested area. However, in the vicinity of Taunton, Mass., near which in 1931 and 1932 several large colonies of *Z. flavo-orbitalis* were released, the parasite became established and maintained itself, although in very small numbers, for several years without additional releases. This continued recovery demonstrated the capability of the species to survive New England winter temperatures to some extent, but its sparse population in southeastern Massachusetts and its failure to become established at other points may be ascribed to its imperfect adaptation to low temperatures.

RÉSUMÉ OF THE STATUS OF ZALEPTOPYGUS FLAVO-ORBITALIS

This ichneumonid, which originated in the Orient, was released at a number of test points in the United States, but permanent establishment was indicated only in the vicinity of Taunton, Mass., where it was present in 1941 in very small numbers. The records of its world distribution and host relations show that it is nonspecific and is adapted to warm regions, such as southern India, southern Japan, the Philippines, and Hawaii. The elapsed time since its release in Virginia has not been sufficient to justify drawing conclusions, but it seems possible that a more southern habitat may be more conducive to its successful establishment.

PHAEOGENES NIGRIDENS Wesm. (Fig. 26)

Order: Hymenoptera.
Family: Ichneumonidae.
Imported from: Europe and Japan.
Preferred host stage: 1- and 2-day-old pupae.
Method of parasitization: Perforates freshly formed pupae with ovipositor and lays egg free in body cavity of host.
Hibernation: As an adult female.

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Phaeogenes nigridens is the only imported parasite of the corn borer released in the United States that attacks the host in the pupal stage. Information on this parasite, as obtained from observations in Europe, have been published by Smith (*32*).

COLONIZATION

The first release of *Phaeogenes nigridens* in the United States was made in 1924, when a single colony was liberated at Arlington, Mass. Releases of European stock, beginning in 1926 in the Lake States, continued to be made in the Eastern and Lake States through 1932. In 1931 a small colony of 38 adults received from Japan was released at Bridgewater, Mass.

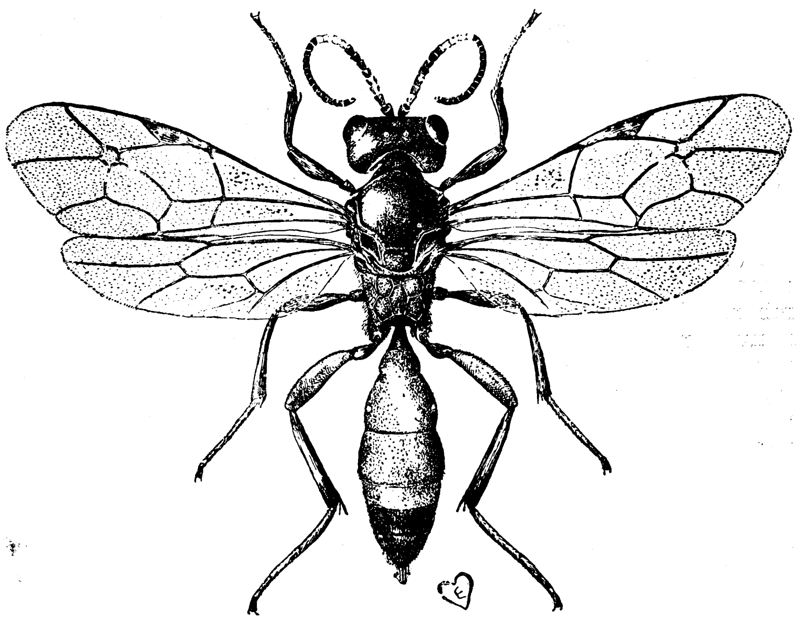

FIGURE 26.—*Phaeogenes nigridens*, adult female. × 10.

From host material collected at the earlier release points, parasite adults were obtained in sufficient numbers to make small releases in 1932, 1933, and 1939. The colonization data for this parasite are given in table 23.

Although importations of this parasite are accomplished more successfully late in the summer than at any other time of year, it was desired to make a test of releases made early in the spring. In August 1937 a consignment of *Phaeogenes nigridens* in the adult stage was received from Europe, and this material was used in experiments to determine the best method of handling the adults through the winter. Eight hundred adults, in equal numbers of males and females, were placed in storage at 50° F., 800 at 45°, and 800 at 36°. Each lot of 800 was separated in 3 boxes (about 6 by 6 by 4 inches), one holding 200 adults with

TABLE 23.—*Numbers of Phaeogenes nigridens adults released in the United States, through December 31, 1940*

State and County	Township	Origin[1]	1926	1927	1928	1929	1930	1931	1932	1933	Total[2]
Connecticut:											
New London	Old Lyme	E	0	1,620	0	0	0	0	0	0	1620
Massachusetts:[3]											
Barnstable	Barnstable	E	0	1,349	0	0	0	0	0	0	1.349
Do	Falmouth	E	0	0	0	115	201	0	0	0	316
Bristol	Dighton	E	0	0	0	644	0	0	0	0	644
Do	Swansea	E	0	0	0	0	0	0	7,796	0	7,796
Essex	Peabody	E	0	0	0	0	0	0	363	0	363
Do	Saugus	E	0	0	0	0	13	0	0	0	1,306
Middlesex	Arlington	E	0	0	5	0	0	0	20	0	2,591
Do	Medford	E	2,288	0	0	0	0	0	0	0	2,288
Norfolk	Quincy	E	0	2,736	3	0	0	0	0	0	2,739
Plymouth	Bridgewater	O	0	0	0	0	0	38	0	0	38
Suffolk	Revere	E	2,455	0	0	0	0	0	0	0	2,455
Total			4,743	4,085	8	759	214	38	8,179	0	21,885
Michigan:											
Monroe	Erie	E	1,161	2,218	322	20	0	0	0	0	3,721
St. Clair	Columbus	E	0	0	0	212	0	0	0	0	212
Total			1,161	2,218	322	232	0	0	0	0	3,933
New Jersey:[4]											
Burlington	Burlington	E	0	0	0	0	0	0	0	0	2,048
Monmouth	Atlantic	E	0	0	0	0	0	0	0	0	1,989
Total			0	0	0	0	0	0	0	0	4,037

TABLE 23.—*Phaeogenes nigridens adults released in the United States through December 31, 1940—Con.*

State and County	Township	Origin[1]	1926	1927	1928	1929	1930	1931	1932	1933	Total[2]
New York:											
Cattaraugus Indian Res.		E	0	0	0	380	0	0	0	0	380
Erie	Lancaster	E	0	0	0	169	0	0	0	0	169
Suffolk	Southold	D	0	0	0	0	0	0	0	20	20
Total			0	0	0	549	0	0	0	20	569
Ohio:											
Henry	Damascus	E	0	0	0	0	0	2,289	0	0	2,289
Lucas	Jerusalem	E	0	1,994	0	121	1,793	2,096	0	0	6,004
Wood	Perry	D	0	0	0	0	0	0	0	13	13
Total			0	1,994	0	121	1,793	4,385	0	13	8,306
Pennsylvania:											
Crawford	Greenwood	E	0	0	0	347	0	0	0	0	347
Rhode Island:											
Newport	Portsmouth	E	0	0	0	0	0	0	8,239	0	8,239
Do	do	D	0	0	0	0	0	0	156	8	164
Providence	E. Providence	E	0	0	943	0	2,516	175	0	0	3,634
Total			0	0	943	0	2,516	175	8,395	8	12,037
Total, United States			5,904	9,917	1,273	2,008	4,523	4,598	16,574	41	52,734

[1] D, Domestic; E, Europe; O, the Orient.

[2] The totals in this column include the numbers given in the footnotes to this table.

[3] In 1924, 1,460 (E) adults were liberated in Arlington Township, Middlesex County, and in 1925, 1,293 adults were liberated in Saugus Township, Essex County, and 1,106 (E) adults in Arlington Township, Middlesex County.

[4] In 1938, 2,015 (E) adults were liberated in Burlington Township, Burlington County, and 1,989 (E) adults in Atlantic Township, Monmouth County; in 1939, 33 (E) adults were liberated in Burlington Township, Burlington County.

no food, another holding 300 adults with available sugar solution, and a third holding 300 adults with a mixture of dry honey and confectioner's sugar. About an equal number of adults were stored in outdoor cages, one containing shocked cornstalks and another forest litter and debris.

By the latter part of September no living adults were noted in the outdoor cage except a number of females in the cage containing cornstalks. Females were alive at this time in the various cages placed in cold storage, but most of the males were dead.

An examination in December 1937 of all cages in which adults were being held in cold storage showed only 152 females alive. Although it was expected that all males would die, it had not been anticipated that the females would incur such a high mortality. Probably the death of the females was attributable to the conditions under which they were stored or to the amount and type of food available, or both, since 135 of the living adults were in one box that had been stored at 50° F. with solid honey-sugar as food.

By the following spring only 18 females were alive in the cages that had been carried in cold storage, and no adults were living in the outdoor cages.

In August 1938, another shipment of adult parasites and parasitized host pupae was received from Italy. About half the adults that became available from this source were released shortly after receipt and the remainder were used in another attempt to store the species through the winter. No adults survived the hibernation period.

FIELD STATUS

Phaeogenes nigridens was first recovered in the summer of 1925 at Arlington, Mass., following large releases made that year. The parasite was taken at Medford in 1926, and at Medford and Saugus in 1927. In 1929 adults of *P. nigridens* emerged from cornstalks heavily infested with *Pyrausta* obtained at Medford, Mass., and from pupae collected during the summer at the same point. These recoveries showed maintenance of the species for a period of 3 years in the absence of supporting releases at this point.

In 1937 *Phaeogenes nigridens* appeared in collections near Waltham and Peabody, Mass. The presence of this pupal parasite was corroborated in 1938 by recoveries in greater numbers from two general districts in Massachusetts, one in the vicinity of Arlington, Waltham, and Lexington, and another near Danvers and Peabody. No *P. nigridens* appeared in collections taken between these two districts. Initial establishment of the species was noted in 1938 at Burlington Township, Burlington County, N. J., where one specimen was recovered in a collection made 12 days after the adult parasites were released.

No surveys have been made in the Lake States area expressly to investigate the status of *Phaeogenes nigridens*. However, in Jerusalem Township, Lucas County, enough pupae were observed in the field to disclose the presence of the parasite had it been present in considerable numbers.

RÉSUMÉ OF THE STATUS OF PHAEOGENES NIGRIDENS

Phaeogenes nigridens is known to be on a maintenance basis at only one point in the United States, a restricted area in eastern Massachusetts. However, surveys designed specifically to determine its status have been made only at a limited number of points, and it is possible that it may be more generally distributed than is known at present. With an increased knowledge of optimum storage conditions for the adults, and attendant synchronization of releases with a preferred stage of the host early in the year, wider establishment may be accomplished.

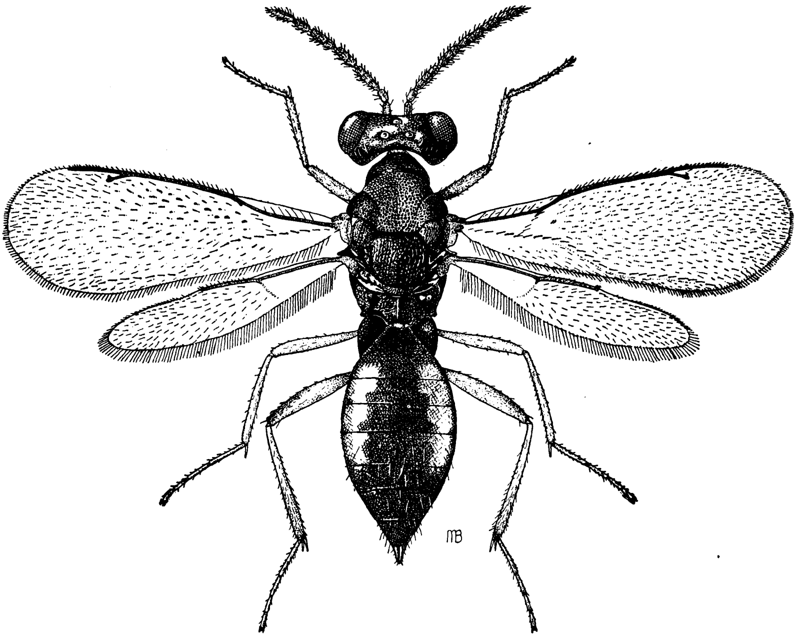

FIGURE 27.—*Eulophus viridulus*, adult female. × 24.

EULOPHUS VIRIDULUS Thoms. (Fig. 27)

Order: Hymenoptera.
Family: Eulophidae.
Imported from: Italy.
Method of parasitization: Egg deposited externally after paralyzing host.
Preferred host stage: Mature larva. Third- and fourth-instar larvae also attacked.
Hibernation: As pupa in host tunnel near host remains.

Information relative to this eulophid parasite of the European corn borer has been published by Parker and Smith (*26*). It is the only species of the introduced parasites that has been transported as a free pupa, and it is one of three imported corn borer parasites that is ectophagous throughout its larval life.

TABLE 24.—*Numbers of Eulophus viridulus adults released in the United States through December 31, 1940*

State and County	Township	1930	1931	1932	1933	1934	Total
Connecticut:							
Hartford	E. Hartford	0	0	0	0	5,097	5,097
New Haven	Milford	0	0	0	0	5,240	5,240
New London	East Lyme	0	993	5,870	0	0	6,863
Total		0	993	5,870	0	10,337	17,200
Indiana: Steuben	York	0	4,466	2,205	0	0	6,671
Massachusetts:							
Barnstable	Falmouth	233	6,730	0	0	0	6,963
Bristol	Swansea	0	0	29,980	0	0	29,980
Essex	Peabody	0	0	9,513	0	0	9,513
Do	Saugus	479	24,530	0	0	0	25,009
Middlesex	Arlington	15	200	350	0	0	565
Plymouth	Bridgewater	0	0	12,756	0	0	12,756
Total		727	31,460	52,599	0	0	84,786
Michigan:							
Lenawee	Fairfield	0	0	2,910	0	755	3,665
Monroe	Erie	0	0	20,081	0	0	20,081
Do	Monroe	0	4,470	2,176	0	0	6,646
Oakland	Oxford	0	0	2,219	0	42	2,261
St. Clair	Columbus	0	6,943	2,209	0	0	9,152
Washtenau	Augusta	0	0	2,232	0	0	2,232
Total		0	11,413	31,827	0	797	44,037

TABLE 24.—*Eulophus viridulus adults released in the United States through December 31, 1940*—Con.

State and County	Township	1930	1931	1932	1933	1934	Total
New York:							
Cattaraugus Indian Res.		0	4,997	0	0	0	4,997
Jefferson	Adams	0	4,991	24,750	0	0	29,741
Suffolk	Southold	0	0	0	21,017	0	21,017
Total		0	9,988	24,750	21,017	0	55,755
Ohio:							
Erie	Perkins	0	1,990	2,186	0	0	4,176
Hancock	Marian	0	0	6,643	0	0	6,643
Henry	Damascus	0	11,397	11,751	0	0	23,148
Huron	Richmond	0	0	2,232	0	0	2,232
Lucas	Jerusalem	0	4,959	7,608	0	0	12,567
Putnam	Jennings	0	0	5,862	0	0	5,862
Wood	Perry	0	0	0	20,958	1,792	22,750
Do	Webster	0	0	24,270	0	0	24,270
Total		0	13,346	60,552	20,958	1,792	101,648
Rhode Island:							
Newport	Portsmouth	0	0	595	338	0	933
Providence	E. Providence	191	6,322	0	0	0	6,513
Total		191	6,322	595	338	0	7,446
Total, United States		918	82,988	178,398	42,313	12,926	317,543

COLONIZATION

The first releases of *Eulophus viridulus* were made in the United States in 1930, when four small colonies were liberated, three in Massachusetts and one in Rhode Island. Introductions and releases were made during the following 4 years in the Eastern and Lake States.

The data on these releases are presented in table 24.

In handling this species after receipt and winter storage at the laboratory, it was necessary to exercise particular care to avoid including secondary parasites in the colonization shipments. About 1 percent of the pupae of *Eulophus viridulus* were attacked by *Tetrastichus* sp., which bore a superficial resemblance to the primary eulophid. In the emergence chambers the emerging adults were drawn by light attraction to a panel covered with white poplin cloth. On this smooth surface the characteristics of the species present were easily discernible and they were readily segregated. Large colonies were released in all cases when enough adults were available.

FIELD STATUS

No recovery of *Eulophus viridulus* has ever been made in the Eastern States. In the Lake States, where most of the releases were made in 1932, this ectophagous eulophid parasite appeared for the first time on a maintenance basis during the 1938 season. It was first discovered during an examination in Lucas County, Ohio, of an infestation of *Pyrausta nubilalis* in weeds in August. *E. viridulus* had been recovered at three release points in the Lake States, namely; Columbus Township, St. Clair County, Mich., in 1931 and 1932; Damascus Township, Henry County, in 1931; and Webster Township, Wood County, Ohio, in 1932. At each location release had been made during the year of recovery. The finding of *E. viridulus* in Jerusalem Township, Lucas County, Ohio, in 1938 represented the first recovery of the species at this point and showed maintenance for 6 years.

The discovery of the parasite in weeds early in August conforms with the recorded habits of the species in Europe, where the summer generation is found on hemp and the fall and overwintering generations on corn.

Borers killed by this parasite were recovered in 1938 from each of 12 collections taken in the vicinity of Jerusalem Township, Lucas County, Ohio, 8 of the 12 sections being on the west side of the release center. The maximum distance at which the parasites were recovered was about 5 miles. One cluster was taken in 1938 near a release point in Erie Township, Monroe County, Mich., where 20,081 adults were released in 1932. One cluster was recovered in 1938 in Danbury Township, Ottawa County, Ohio, at a point 8 miles from the nearest release center, 4 miles of this distance being across the water of Sandusky Bay. The number of pupae per cluster ranged from 1 to 48, with an average of 8.7.

Upon receipt at the laboratory, each cluster of *Eulophus viridulus* recovered in the United States in 1938 was divided, where possible, one-half of the pupae being placed in cold storage and

the other half being held in a developmental environment in an incubator. No emergence from the latter material was noted until late in the winter, which indicated that the diapause requirements of this species are particularly effective.

That this parasite differs in its dispersion characteristics from other parasites of the European corn borer is indicated by information obtained in the fall of 1939 and that of 1940. During these two years, observations were made in the following counties in Ohio: Allen, Auglaize, Erie, Hardin, Henry, Logan, Lucas, Sandusky, Seneca, and Wood. In some of the counties only one observation per township was made and in others only a few townships were included. However, *Eulophus viridulus* was recovered at one or more points in each of the counties. One cluster was found over 50 miles from the nearest release point, and the farthest limits of dispersion were not defined by this survey.

Thus, unlike other corn borer parasites, which build up to considerable concentrations in the immediate vicinity of the release point and spread slowly outward, it has been shown that *Eulophus viridulus* is capable of rapidly extending its range without greatly increasing in abundance in any locality.

ALTERNATE HOSTS

Larvae of *Pyrausta ainsliei* Heinrich and *P. penitalis* Grote collected in Jerusalem Township, Lucas County, Ohio, in August 1938, were parasitized in the field by *Eulophus viridulus.* This constituted the second record observed by Bureau personnel of an exotic parasite of the European corn borer attacking native borers in the United States. Parasite pupae and pupal exuviae were noted among the parasites taken in August on *P. ainsliei* and *P. nubilalis,* but only pupal exuviae were noted in association with *P. penitalis.*

Preliminary data resulting from more extensive surveys made in 1939 to obtain information on the distribution of *Eulophus viridulus* indicate that it has an extended range about several release points in Ohio.

RÉSUMÉ OF THE FIELD STATUS OF EULOPHUS VIRIDULUS

Apparently several years have been necessary to bring the population of this eulophid to sufficient density to permit recovery by the means utilized. However, the fact of its recovery indicates that it has increased in abundance since its release. Although the species has not been recovered in the Eastern States, it might prove to be of value if released in some of the areas more recently infested by the host.

IMPORTED PARASITES NOT KNOWN TO BE ESTABLISHED IN THE UNITED STATES

The parasites treated in the preceding discussion comprise those which, following releases of 1 or more years, have become established in one or more localities in varying abundance, through several generations of the host, without the aid of supporting releases.

The following species are those that have been imported and released in the United States, but at the close of the 1940 season cannot be considered as being established.

EXERISTES ROBORATOR (F.) (Fig. 28)

Order: Hymenoptera.
Family: Ichneumonidae.
Imported from: Europe.
Preferred host stage: Mature larva.

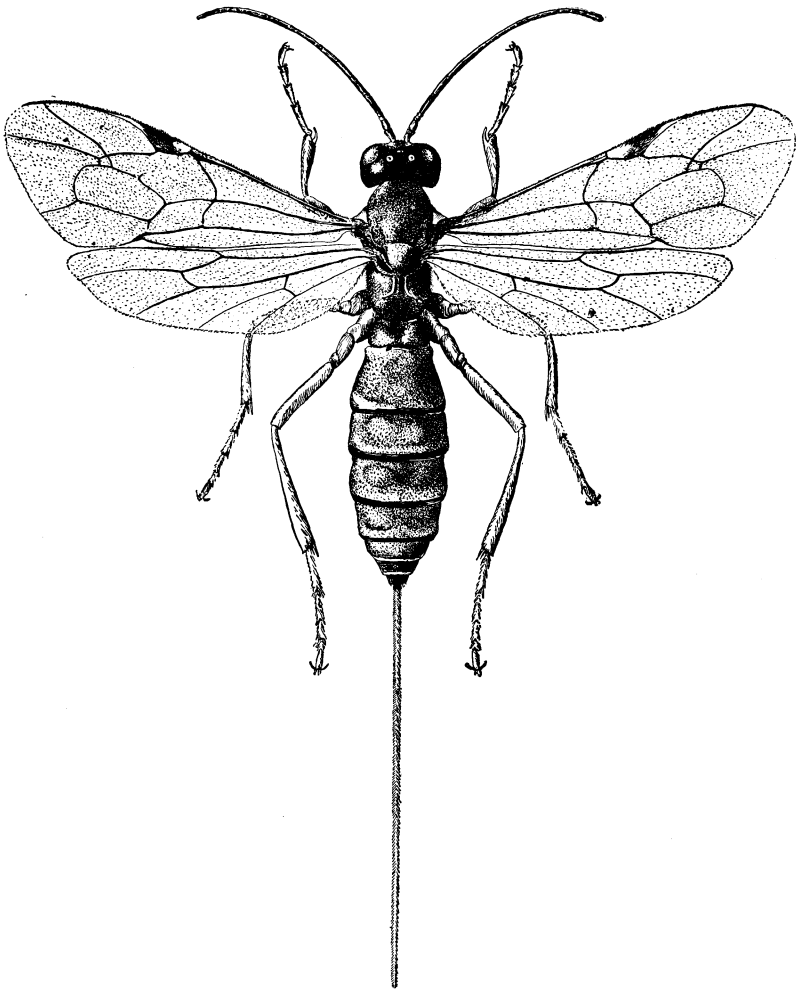

FIGURE 28.—*Exeristes roborator*, adult female. × 4.

Method of parasitization: Ovipositor inserted through plant tissue and host paralyzed by stinging, and eggs laid ectodermally.
Hibernation: As a mature larva or pupa in a loosely woven cocoon.

TABLE 25.—*Numbers of Exeristes roborator adults released in the United States, through December 31, 1940*

State and County	Township	1923	1924	1925	1926	1927	1928	1929	1930	Total[1]
Illinois: Washington	Will	0	0	0	0	362	1,940	0	0	2,302
Indiana:										
De Kalb	Butler	0	0	0	0	0	0	3,991	1,983	5,974
Do	Spencer	0	0	0	1,374	5,170	574	0	0	7,118
Elkhart	Elkhart	0	0	0	0	1,948	1,875	0	0	3,823
Steuben	York	0	0	0	0	0	0	3,997	1,993	5,990
Total		0	0	0	1,374	7,118	2,449	7,988	3,976	22,905
Massachusetts:[2]										
Barnstable	Chatham	0	0	1,200	0	0	0	0	0	1,200
Essex	Saugus	7,219	0	0	0	0	0	0	0	7,275
Middlesex	Arlington	7,159	11,341	4,300	0	0	0	0	0	22,800
Do	Cambridge	7,298	0	0	0	0	0	0	0	7,298
Do	Malden	7,259	0	3,500	0	0	0	0	0	10,759
Do	Medford	0	0	5,330	295	0	0	0	0	5,625
Total		28,935	11,341	14,330	295	0	0	0	0	54,957
Michigan:										
Jackson	Napoleon	0	0	0	0	1,682	0	0	0	1,682
Lenawee	Fairfield	0	0	0	0	0	0	3,985	1,986	5,971
Macomb	Harrison	0	0	0	0	1,910	0	0	0	1,910
Monroe	Erie	0	0	0	8,093	5,782	7,853	0	0	21,728
Do	Lasalle	0	0	0	0	1,964	0	0	0	1,964
Do	Monroe	0	0	0	6,752	8,462	3,890	0	0	19,104
Oakland	Oxford	0	0	0	0	0	0	3,985	1,996	5,981
St. Clair	Columbus	0	0	0	2,793	4,122	7,775	0	0	14,690
Washtenaw	Augusta	0	0	0	0	0	0	3,841	1,998	5,839
Do	Northfield	0	0	0	0	0	5,891	0	0	5,891
Wayne	Brownstone	0	0	0	0	1,847	0	0	0	1,847
Total		0	0	0	17,638	25,769	25,409	11,811	5,980	86,607

New York:										
Cattaraugus Indian Res.		0	2,662	2,963	5,350	2,014	0	0	0	12,989
Do	Randolph	0	0	0	0	0	0	3,998	1,989	5,987
Chautauqua	Westfield	0	0	0	0	0	1,898	0	0	1,898
Erie	Lancaster	0	0	0	0	0	0	0	1,530	1,530
Genesee	Batavia	0	0	0	0	0	5,017	3,998	1,962	10,977
Jefferson	Adams	0	0	0	0	0	0	0	1,995	1,995
Wyoming	Java	0	0	0	0	0	0	2,700	1,974	4,674
Total		0	2,662	2,963	5,350	2,014	6,915	10,696	9,450	40,050
Ohio:[3]										
Ashtabula	Ashtabula	0	0	0	0	1,919	0	0	0	1,919
Erie	Perkins	0	1,375	689	9,670	2,000	0	0	0	13,734
Hancock	Marion	0	0	0	0	0	0	3,985	1,994	5,979
Henry	Damascus	0	0	0	0	0	0	0	4,974	5,933
Huron	Richmond	0	0	0	0	0	5,842	4,000	1,990	11,832
Lake	Mentor	0	1,462	2,150	4,085	1,908	5,603	0	0	15,208
Lorain	Avon	0	0	0	0	1,609	0	0	0	1,609
Lucas	Jerusalem	0	2,888	2,235	7,545	3,482	6,031	0	0	22,181
Ottawa	Carroll	0	0	0	0	1,726	0	0	0	1,726
Summit	Northampton	0	0	0	0	0	0	3,975	1,985	5,960
Wood	Troy	0	0	0	0	1,745	0	0	0	1,745
Total		0	5,725	5,074	21,300	14,389	17,476	11,960	10,943	87,826
Pennsylvania:										
Crawford	Wayne	0	0	0	0	0	5,707	3,986	1,993	11,686
Erie	Harbor Creek	0	0	0	2,450	3,983	0	0	2,000	8,433
Total		0	0	0	2,450	3,983	5,707	3,986	3,993	20,119
Total United States		28,935	19,728	22,367	48,407	53,635	59,896	46,441	34,342	314,766

[1] The totals include the numbers given in the footnotes to this table.

[2] In 1922, 56 parasites from Europe were liberated in Saugus Township, Essex County.

[3] In 1931, 959 parasites were liberated in Damascus Township, Henry County.

Various phases of the life history and habits of *Exeristes roborator* under laboratory- and field-cage conditions have been studied by Fox (*15*) and Baker and Jones (*2*).

COLONIZATION

Exeristes roborator, the largest of the imported hymenopterous parasites, has been colonized with material bred in parasite laboratories in the United States, except for 56 individuals released in 1922.

Following receipt of breeding stock in 1922, releases of reared material were made in the Eastern States yearly through 1926. All liberations in the eastern area were confined to two sites in Massachusetts—one at Chatham, in Barnstable County, and the other at the multiple-release point centering at Malden, Middlesex County.

A large number of parasites reared at the Arlington, Mass., laboratory were shipped in the "spin-up" stage for release in the Lake States. In 1926 the laboratory rearing of *Exeristes roborator* was started at Monroe, Mich., and material thus obtained served to augment the release material shipped from Massachusetts. Liberations were made in the Lake States yearly from 1924 to 1931, inclusive. The releases of this species in the United States are listed in table 25.

FIELD STATUS

Although five other species of parasites were liberated in the United States prior to the first release of *Exeristes roborator*, that parasite was the first to be recovered. The releases made early in 1923 were apparently particularly effective, since in June of that year initial establishment was recorded from six towns in the immediate vicinity of Malden, Mass., one recovery being 5 miles from the nearest point of release. Daily observations on borers at East Arlington, Mass., in the summer of 1923 showed 5 to 8 percent parasitization by this species. Recoveries continued to be made in eastern Massachusetts yearly from 1923 through 1926. In each of these years supporting releases were made in this locality. However, it seems probable that the parasite maintained itself through more than one generation in the eastern area, because in 1926 it was numerous in infested cornstalks collected at Saugus, Mass., in August, although the only liberation made that year consisted of a small colony at Medford.

With the conclusion of colonization activities with this species in the East, further recoveries ceased. Since observations have been made in eastern Massachusetts in varying detail yearly since 1926, with no appearance of the species, its failure to become permanently established is strongly indicated.

In the Lake States area the first recoveries were made in 1925 in Perkins Township, Erie County, Ohio, and at the Cattaraugus Indian Reservation in New York.

Details of its field status from 1927 through 1932 in this area have been presented by Baker and Jones (*2*), who point out the apparent inability of the species to exist for more than one gen-

eration in areas where the predominating hosts have a single generation per year.

SHIPMENTS OF EXERISTES ROBORATOR FOR TRIAL AGAINST PESTS OTHER THAN THE EUROPEAN CORN BORER

Owing largely to the ease with which this species could be produced and because of its polyphagous habits in the country of its origin, a considerable amount of material, reared in the European corn borer research laboratories in the United States, was shipped for testing against other pests. In 1926 and 1927, spin-ups of *Exeristes roborator* were shipped from Monroe, Mich., to Guam for tests against the European corn borer on that island. Notwithstanding the distance involved, the method of shipment utilized proved successful, an emergence of 70 percent being obtained. In 1928, 2,000 adults were sent to New Orleans, La., for trial against the sugarcane borer (*Diatraea saccharalis* (F.)). Another shipment of adults was made in 1932, to El Paso, Tex., to be utilized in tests against the pink bollworm (*Pectinophora gossypiella* (Saund.)).

RÉSUMÉ OF THE STATUS OF EXERISTES ROBORATOR

Since observations in recent years have failed to disclose the presence of *Exeristes roborator* in any locality studied, it seems probable that the species is not established in the United States, and there is a strong indication that it is unable to maintain itself in any of the regions where it has been released. Its failure to do so is apparently due to the lack of synchronization between the seasonal history of the parasite and that of its host. Such synchronization seems to be somewhat closer in the extremely limited area tested in the northeastern section of host infestation. It is possible that farther south, along the Atlantic seaboard, changes in the seasonal rhythm of the host might be encountered. Such changes would function more to the advantage of the parasite.

MICROBRACON BREVICORNIS (Wesm.) (Fig. 29)

Order: Hymenoptera.
Family: Braconidae.
Imported from: France.
Preferred host stage: Mature larvae.
Method of parasitization: Paralyzes host by stinging. Deposits 10 to 20 eggs per host ectodermally.
Hibernation: No definite resting period.

The life history of this species has been published by Genieys (*16*) and the essential features of its laboratory production have been described by Jones (*18*).

COLONIZATION

As with *Exeristes roborator*, colonization of *Microbracon brevicornis* has been accomplished almost entirely with material reared in the corn borer research laboratories of the United States. In 1920 a few females were received for use in reproduction experi-

TABLE 26.—*Numbers of Microbracon brevicornis adults released in the United States, through December 31, 1940*

(All parasites bred in the laboratory except as indicated in footnote 2)

State and County	Township	1922	1924	1925	1926	1927	1928	1929	1930	1938	Total[1]
Connecticut: Hartford	E. Hartford	0	0	0	0	0	0	0	0	4,952	4,952
Illinois: Washington	Will	0	0	0	0	3,635	0	0	0	0	3,635
Indiana:											
De Kalb	Butler	0	0	0	0	0	0	31,442	14,958	0	46,400
Do	Spencer	0	0	0	0	11,000	0	0	0	0	11,000
Steuben	York	0	0	0	0	0	0	32,472	15,237	0	47,709
Total		0	0	0	0	11,000	0	63,914	30,195	0	105,109
Maryland:											
Worcester	Newark	0	0	0	0	0	0	0	0	1,616	1,616
Massachusetts:[2]											
Barnstable	Chatham	0	0	10,600	0	0	0	0	0	0	10,600
Essex	Saugus	0	0	0	0	0	0	0	0	0	320
Do	do	270,000	0	0	0	0	0	0	0	0	270,000
Middlesex	Arlington	0	0	0	0	0	0	0	0	0	80
Do	do	260,000	0	0	0	0	0	0	0	0	260,000
Do	Cambridge	254,000	0	0	0	0	0	0	0	0	254,000
Do	Malden	270,000	0	0	0	0	0	0	0	0	270,000
Do	Medford	0	0	9,440	0	0	0	0	0	0	9,440
Do	Waltham	0	0	7,830	2,320	0	0	0	0	0	10,150
Total		1,054,000	0	27,870	2,320	0	0	0	0	0	1,084,590

Michigan:											
Jackson	Napoleon	0	0	0	0	9,455	19,440	0	0	0	28,895
Lenawee	Fairfield	0	0	0	0	0	18,192	40,751	14,468	0	73,411
Macomb	Harrison	0	0	0	0	8,440	17,865	0	0	0	26,305
Monroe	Erie	0	0	0	19,600	4,100	29,958	0	0	0	53,658
Do	LaSalle	0	0	0	0	0	18,960	0	0	0	18,960
Do	Monroe	0	0	0	11,458	59,840	32,760	0	0	0	104,058
Oakland	Oxford	0	0	0	0	0	19,070	37,395	15,473	0	71,938
St. Clair	Columbus	0	0	0	15,079	16,640	19,628	0	0	0	51,347
Washtenaw	Augusta	0	0	0	0	0	0	35,397	14,280	0	49,677
Do	Northfield	0	0	0	0	0	20,605	0	0	0	20,605
Wayne	Brownstone	0	0	0	0	10,500	24,980	0	0	0	35,480
Total		0	0	0	46,137	108,975	221,458	113,543	44,221	0	534,334
New Jersey:											
Burlington	Burlington	0	0	0	0	0	0	0	0	5,994	5,994
Monmouth	Atlantic	0	0	0	0	0	0	0	0	5,863	5,863
Total		0	0	0	0	0	0	0	0	11,857	11,857
New York:											
Cattaraugus Indian Res.		0	25,000	8,500	7,800	36,093	52,117	0	0	0	129,510
Do	Randolph	0	0	0	0	0	19,812	23,855	14,984	0	58,651
Chautauqua	Portland	0	0	0	0	0	11,030	0	14,427	0	11,030
Erie	Lancaster	0	0	0	0	0	0	0	14,988	0	14,988
Genesee	Batavia	0	0	0	0	0	21,183	24,169	0	0	59,779
Jefferson	Adams	0	0	0	0	0	0	0	13,873	0	13,783
Suffolk	Riverhead	0	0	0	0	0	0	0	0	4,971	4,971
Wyoming	Java	0	0	0	0	0	20,527	26,082	14,944	0	61,553
Total		0	25,000	8,500	7,800	36,093	124,669	74,106	73,126	4,971	354,265

TABLE 26.—*Microbracon brevicornis adults released in the United States through December 31, 1940—Con.*

(All parasites bred in the laboratory except as indicated in footnote 2)

State and County	Township	1922	1924	1925	1926	1927	1928	1929	1930	1938	Total[1]
Ohio:[3]											
Ashtabula	Ashtabula	0	0	0	0	10,200	20,750	0		0	30,950
Erie	Perkins	0	25,550	90,000	1,826	15,000	16,683	0	0	0	149,059
Hancock	Marion	0	0	0	0	0	25,220	24,527	14,657	0	64,404
Henry	Damascus	0	0	0	0	0	0	0	58,529	0	68,220
Huron	Richmond	0	0	0	0	0	20,678	23,901	14,450	0	59,029
Lake	Mentor	0	0	0	461	20,000	7,500	0	0	0	27,961
Lorain	Avon	0	0	0	0	0	18,630	0	0	0	18,630
Lucas	Jerusalem	0	0	30,000	740	10,030	37,730	0	0	0	78,500
Ottawa	Carroll	0	0	0	0	7,200	20,520	0	0	0	27,720
Summit	Northampton	0	0	0	0	0	17,430	25,880	14,800	0	58,110
Wood	Troy	0	0	0	0	5,000	0	0	0	0	5,000
Total		0	25,550	120,000	3,027	67,430	185,141	74,308	102,436	0	587,583
Pennsylvania:											
Crawford	Wayne	0	0	0	0	0	30,445	28,216	14,762	0	73,423
Erie	Harbor Creek	0	0	0	6,300	11,930	20,574	0	15,078	0	53,882
Total		0	0	0	6,300	11,930	51,019	28,216	29,840	0	127,305
Virginia:											
Accomac	Lee	0	0	0	0	0	0	0	0	2,186	2,186
Northampton	Franktown	0	0	0	0	0	0	0	0	2,971	2,971
Total		0	0	0	0	0	0	0	0	5,157	5,157
Total, United States		1,054,000	50,550	156,370	65,584	239,063	582,287	354,087	279,818	28,553	2,820,403

[1] The totals in this column include the numbers given in footnotes to this table.

[2] In 1921, 320 parasites from Europe were liberated in Saugus Township, Essex County, and 80 in Arlington Township, Middlesex County.

[3] In 1931, 9691 parasites bred in the laboratory were liberated in Damascus Township, Henry County.

ments. The following year 1,210 cocoons and 15 adults were imported. From this material two small colonies, totaling 400 individuals, were released in eastern Massachusetts and the remainder served as a nucleus breeding stock. From this stock, together with a small amount of material imported in 1935, originated the colonization material, totaling over 2½ million adults, released in subsequent years.

The history of the laboratory reproduction and colonization of *Microbracon brevicornis* in the United States parallels closely that of *Exeristes roborator*. Breeding at the Arlington, Mass., laboratory continued from 1921 through 1926, some of the material reared in 1924, 1925, and 1926 being shipped for release in the Lake States area.

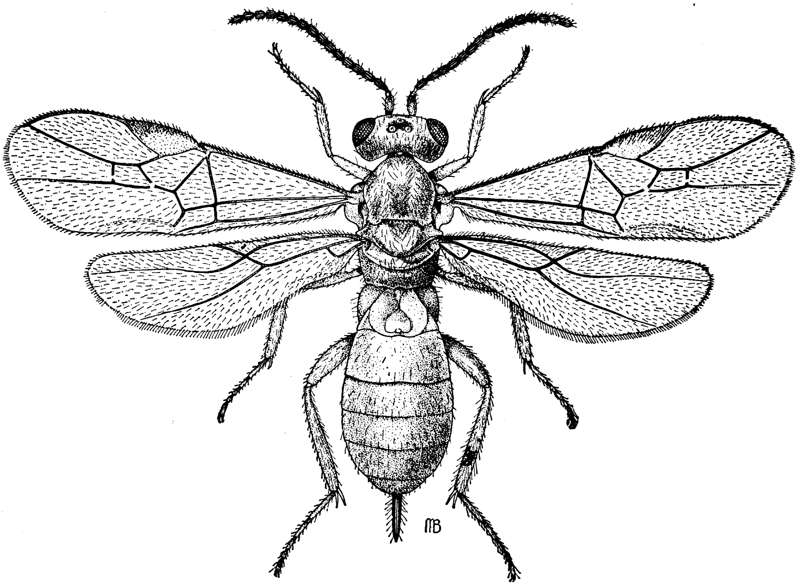

FIGURE 29.—*Microbracon brevicornis*, adult female. × 22.

In 1926 production was initiated at the Monroe, Mich., laboratory, and colonization material for release at points in the Lake States area was reared at that laboratory yearly from 1926 through 1931. This species was also reared at the Moorestown, N. J., corn borer laboratory in 1938 to furnish adults for test releases in the Atlantic Coast States as far south as Virginia. A total of 28,553 adults were released, but no recovery of this species had been made in this area through 1940. Colonization data for the species are given in table 26.

FIELD STATUS

Notwithstanding the fact that a greater number of *Microbracon brevicornis* adults have been released in the United States than of any other corn borer parasites, no recovery of the species has

ever been made, although over ½ million borers from sites where the species has been colonized have been under observation.

Unlike other parasites that have become established, no logical reason for the failure of *Microbracon brevicornis* has presented itself. In certain European districts where this parasite is abundant, the practice prevails of stacking the corn through the winter in long rows of shocks laid against an elevated horizontal rail or of piling it in large ricks. It has been noted that the *M. brevicornis* females are especially abundant around such rows or stacks of corn, the parasitization in these locations averaging as high as 62 percent. It was thought that such an agricultural practice might afford the needed protection for the overwintering parasites. Experiments were therefore conducted in both the

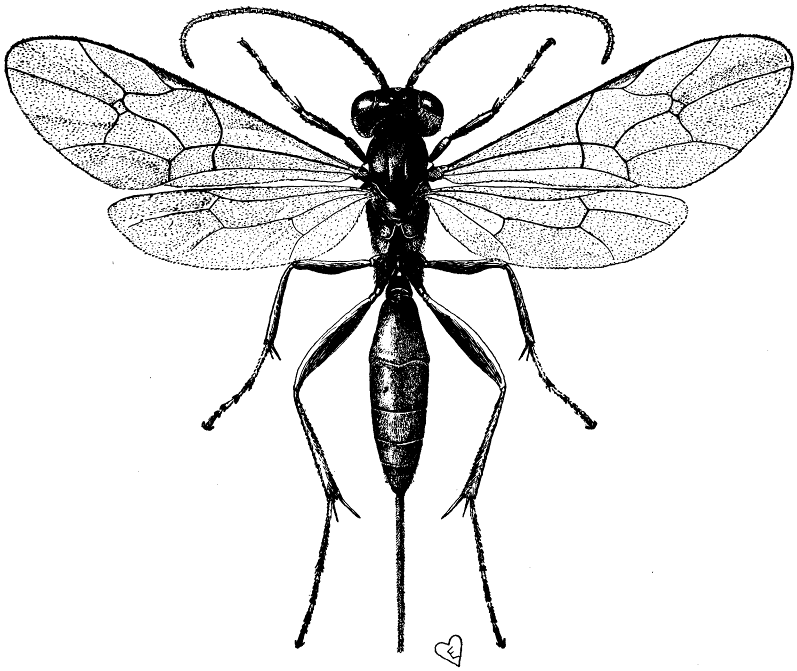

FIGURE 30.—*Campoplex alkae*, adult female. × 5.

Eastern and the Lake States areas, in which the European conditions were simulated as closely as possible. Large numbers of *M. brevicornis* adults and corn heavily infested with corn borer larvae were utilized in these tests. No recovery was ever obtained in these experiments. Individuals that would have propagated readily in the laboratory failed to produce offspring when released near the test shocks. It was also found that the adults failed to overwinter when released in screened cages containing infested corn shocks.

EXPERIMENTS WITH ASSOCIATED INSECTS

In 1920 larvae of the southern cornstalk borer (*Diatraea crambidoides* (Grote)) were tested in reproduction experiments. It

was found that the female parasites attacked and deposited eggs freely on the *D. crambidoides* larvae. The parasite larvae, however, encountered difficulty in becoming established and did not feed as well as on *Pyrausta nubilalis*, and a much lower average number of parasites per borer was produced. The *D. crambidoides* larvae shortened and disintegrated from bacterial action sooner than did the *P. nubilalis* larvae.

TESTING AGAINST PESTS OTHER THAN THE EUROPEAN CORN BORER

As early as 1920, the year of its introduction into the United States, 400 individuals of *Microbracon brevicornis* were sent to Ames, Iowa, for tests against native borers.

Adults totaling 1,462 were sent to Charlottesville, Va., in 1921 for an experiment in combating the southern cornstalk borer (*Diatraea crambidoides*). The following year 1,000 adults were shipped for a similar purpose, and 1,900 were sent to New Orleans, La., in 1922 to combat the sugarcane borer (*Diatraea saccharalis*). In 1923 a total of 900 adults were sent to Urbana, Ill., for use in experiments on the smartweed borer (*Pyrausta ainsliei*). In 1924, 200 cocoons were shipped to New Orleans for special breeding work. In 1925, 1,200 adults were shipped to Lafayette, Ind., for use against *P. ainsliei*, and in 1926, 2,300 were sent to Ames, Iowa, for experimental studies.

CAMPOPLEX ALKAE (Ell. & Sacht.) (Fig. 30)

Order: Hymenoptera.
Family: Ichneumonidae.
Imported from: Europe, the Orient.
Preferred host stage: Third- and fourth-instar larvae.
Method of parasitization: Egg laid free in body cavity of host.
Hibernation: Larva within closely woven cocoon.

Campoplex alkae bears a close resemblance to another imported ichneumonid parasite, *Horogenes punctorius*, in both the adult and larval stages. The adult of *C. alkae* may be distinguished by the presence of an areolet in the forewings, which is lacking in *H. punctorius*. The diagnostic characters by which the mature larvae may be distinguished are shown in figure 19.

The morphology and biology of *Campoplex alkae* have been treated by Thompson and Parker (*35*) under the name *Eulimneria crassifemur*, and Baker and Arbuthnot (*1*) have discussed phases of its hibernation habits.

The species is generally distributed throughout most of the countries of Europe and, as a result of 3 years of study, was found to be most abundant on that continent in southwestern France. In the Orient it has been found only in Manchuria, and there only in areas where one generation of the host is present; however, higher concentrations of the parasite are recorded there than in any locality in Europe.

TABLE 27.—*Numbers of Campoplex alkae adults released in the United States, through December 31, 1940*

[All parasites from Europe except where indicated]

State and County	Township	1925	1926	1927	1928	1929	1930	1931	1932	Total[1]
Connecticut:										
New London	East Lyme	0	0	0	167	13	683	0	26	889
Do	do [2]	0	0	0	0	0	0	0	168	168
Total		0	0	0	167	13	683	0	194	1,057
Indiana: Steuben	York	0	0	0	0	1,457	1,359	2,345	0	5,161
Massachusetts:[3]										
Barnstable	Chatham	180	0	0	0	0	0	0	0	180
Do	Falmouth	0	0	0	269	364	855	371	0	1,859
Bristol	Dighton	0	0	0	0	37	0	0	0	37
Do	Swansea	0	0	0	0	295	0	0	936	1,231
Do	do [2]	0	0	0	0	0	0	0	82	82
Essex	Peabody	0	0	0	0	0	0	0	111	111
Do	Saugus	223	140	572	0	30	1,171	163	0	2,299
Do	do [2]	0	0	0	0	0	0	161	0	161
Middlesex	Arlington	754	75	610	1,257	2	0	0	14	2,840
Do	Concord	0	0	0	0	0	0	0	881	881
Do	Malden	811	86	722	0	0	0	0	0	7,337
Do	Medford	253	1,004	653	0	0	0	0	87	1,997
Do	do [2]	0	0	0	0	0	0	0	13	13
Do	Watertown	0	0	0	0	0	0	0	0	31
Norfolk	Quincy	0	0	0	491	0	0	0	0	491
Plymouth	Bridgewater[2]	0	0	0	0	0	0	403	7,674	8,077
Suffolk	Revere	0	311	588	0	0	0	0	0	899
Total		2,221	1,616	3,145	2,017	728	2,026	1,098	9,798	28,526

Michigan:										
Lenawee	Fairfield	0	0	0	0	0	606	1,177	0	1,783
Monroe	Erie	0	0	2,777	3,199	0	0	0	2,032	8,008
Do	Monroe	0	0	2,582	1,714	48	0	1,342	2,429	8,115
St. Clair	Columbus	0	0	2,195	1,706	817	1,451	0	0	6,169
Total		0	0	7,554	6,619	865	2,057	2,519	4,461	24,075
New York: [4]										
Cattaraugus Indian Res.		0	0	0	0	2,181	1,735	0	0	3,916
Erie	Lancaster	0	0	0	0	297	0	0	0	297
Jefferson	Adams	0	0	0	0	0	0	1,928	1,929	3,857
Schenectady	Glenville	0	0	0	0	442	71	0	0	513
Suffolk	Southhold	0	0	0	0	0	0	0	0	696
Total		0	0	0	0	2,920	1,806	1,928	1,929	9,279
Ohio: [4]										
Erie	Perkins	0	889	4,251	2,944	0	0	0	0	8,084
Henry	Damascus	0	0	0	0	0	4,372	7,113	2,804	14,289
Lake	Mentor	0	0	2,720	2,540	0	0	0	0	5,260
Lucas	Jerusalem	0	1,052	2,200	3,200	1,410	0	0	0	7,862
Summit	Northampton	0	0	0	0	705	0	0	0	705
Wood	Perry	0	0	0	0	0	0	0	0	198
Total		0	1,941	9,171	8,684	2,115	4,372	7,113	2,804	36,398
Pennsylvania:										
Crawford	Greenwood	0	0	0	0	354	0	0	0	354
Erie	Harbor Cr.	0	0	0	0	196	0	0	0	196
Total		0	0	0	0	550	0	0	0	550

TABLE 27.—*Campoplex alkae adults released in the United States through December 31, 1940—Con.*

[All parasites from Europe except where indicated]

State and County	Township	1925	1926	1927	1928	1929	1930	1931	1932	Total[1]
Rhode Island:[5]										
Newport	Portsmouth	0	0	0	0	0	0	0	1,002	1,085
Providence	E. Providence	0	0	0	717	953	1,033	848	0	3,551
Total		0	0	0	717	953	1,033	848	1,002	4,636
Total, United States		2,221	3,557	19,870	18,204	9,601	13,336	15,851	20,188	109,682

[1] The totals in this column include the numbers given in the footnotes to this table.

[2] From the Orient.

[3] In 1920, 31 from the Orient were liberated in Watertown Township, Middlesex County; in 1921, 4,968 from Europe were liberated in Malden Township, Middlesex County; in 1922, 17 and in 1923, 733 from Europe were liberated in the same township; in 1924, 128 were liberated in Arlington Township, Middlesex County.

[4] In 1933, 696 from Europe were liberated in Southold Township, Suffolk County, and 198 in Perry Township, Wood County.

[5] In 1933, 83 from Europe were liberated in Portsmouth Township, Newport County.

COLONIZATION

Campoplex alkae was one of the first three species of corn borer parasites introduced into the United States, a small colony having been released in Watertown, Mass., in 1920. After that year releases in varying numbers were made annually in the eastern area through 1933. Releases in the Lake States area were first made in 1927 and continued annually through 1933. Adults of Oriental origin were released only in the years 1931 and 1932, although a small number of cocoons and adults were imported in 1930. With the exception of one colony at East Lyme, Conn., all colonies of Oriental material were confined to eastern Massachusetts. Practically all importations and shipments of this species were made while the parasite was in the cocoon stage. Cocoons containing larvae that had not cast their meconia were found to be most suitable for shipping and storage. Data on the United States releases of this species are presented in table 27.

FIELD STATUS

The first recovery of *Campoplex alkae* was from cocoons collected in the winter of 1925–26 at Saugus, Mass. In 1927 it appeared in collections from four towns in the vicinity of Malden, Mass., and in 1929 it was recovered at East Providence, R. I., and Quincy, Mass. The only recoveries of this species in the Lake States area were a few individuals taken in 1929 and 1930 in Jerusalem Township, Lucas County, Ohio. Since 1930 the species has not appeared in the United States. The explanation for its failure to become established permanently is difficult to find. Recovery records in New England indicate that the species has at times been able to reproduce following a summer generation in the field. Apparently in the Lake States there has been no survival for more than one generation. One important factor that would militate against its success is its lack of seasonal rhythm with the host, as discussed by Baker and Arbuthnot (*1*).

Although no hyperparasites have appeared from the few cocoons recovered in the field, it seems probable that hyperparasitization might be a controlling factor, since some material imported from Europe is heavily hyperparasitized. Six species of secondary parasites have been recorded as attacking *Campoplex alkae*, and at times chalcidoids have appeared from imported cocoons, especially of Italian origin, in such numbers as to make collection of the *C. alkae* adults from the emergence cages difficult.

The sex ratio of adults emerging from imported cocoons has always been most satisfactory. From over 41,000 adults recorded from 28 lots ranging in size from 21 to 9,225 individuals, the females averaged 60.6 percent of the total. This proportion varied little from year to year.

The adults are strong fliers and, unlike many parasites that linger for some time in the general vicinity of the release cage, usually make long high flights when liberated.

Studies of this parasite have been made with the use of field cages (fig. 17.). Such studies have fully corroborated the apparently inefficient habit, noted by Thompson and Parker (*35*),

TABLE 28.—*Numbers of Apanteles thompsoni adults released in the United States, through December 31, 1940*

[All parasites released were from Europe except where indicated]

State and County	Township	1926	1927	1928	1929	1930	1931	1932	Total[1]
Connecticut: New London	East Lyme	0	0	500	0	94	0	20,674	21,268
Indiana: Steuben	York	0	0	0	2,346	888	2,466	0	5,700
Massachusetts:[2]									
Barnstable	Falmouth	0	0	4,360	105	497	3,500	0	8,462
Bristol	Swansea	0	0	0	284	0	0	327	611
Essex	Saugus	1,240	5,628	0	0	0	4,510	0	11,378
Middlesex	Arlington	0	5,273	12,127[3]	0	0	0	0	18,127
Do	Concord	0	0	0	0	0	0	2,827	2,827
Do	Malden	0	6,392	0	0	0	0	0	6,392
Do	Medford	1,696	4,680	0	0	0	0	0	8,051
Norfolk	Quincy	0	1,695	6,314	0	0	0	0	8,009
Suffolk	Revere	0	5,282	0	0			0	5,282
Total		2,936	28,950	22,801	389	497	8,010	3,154	69,139
Michigan:									
Lenawee	Fairfield	0	0	0	0	0	1,958	1,573	3,531
Monroe	Erie	0	3,625	0	0	0	0	7,938	11,563
Do	Monroe	0	0	5,871	1,146	0	0	0	7,017
Oakland	Oxford	0	0	0	0	0	1,961	0	1,961
St. Clair	Columbus	0	0	200	3,747	964	2,424	0	7,335
Washtenaw	Augusta			0	0	0	1,975	1,455	3,430
Total		0	3,625	6,071	4,893	964	8,318	10,966	34,837

New York:[4]									
Cattaraugus Indian Res.		0	1,201	22,611	2,609	916	1,973	0	29,310
Cattaraugus	Randolph	0	0	0	0	0	1,993	0	1,993
Chautauqua	Portland	0	0	9,932	0	0	1,970	0	11,902
Erie	Lancaster	0	0	0	1,227	0	1,991	0	3,218
Jefferson	Adams	0	0	0	0	0	1,994	17	2,011
Schenectady	Glenville	0	0	0	58	498	0	0	556
Suffolk	Southold	0	0	0	0	0	0	0	126
Wyoming	Java	0	0	0	0	0	1,990	0	1,990
Total		0	1,201	32,543	3,894	1,414	11,911	17	51,106
Ohio:[5]									
Erie	Perkins	0	904	10,000	0	0	0	0	11,979
Hancock	Marian	0	0	0	0	0	1,981	1,482	3,463
Henry	Damascus	0	0	0	0	477	4,097	2,472	7,046
Huron	Richmond	0	0	0	0	0	1,995	996	2,991
Lake	Mentor	0	0	25	0	0	0	0	25
Lucas	Jerusalem	0	0	9,022	2,577	1,125	0	0	12,724
Putnam	Jennings	0	0	0	0	0	0	1,461	1,461
Summit	Northampton	0	0	0	0	0	1,988	0	1,988
Wood	Perry	0	0	0	0	0	0	0	319
Do	Webster	0	0	0	0	0	0	10,509	10,509
Total		0	904	19,047	2,577	1,602	10,061	16,920	52,505
Pennsylvania:									
Crawford	Greenwood	0	0	0	0	0	2,000	0	2,000
Erie	Harbor Creek	0	0	0	1,778	0	1,996	0	3,774
Total		0	0	0	1,778	0	3,996	0	5,774

TABLE 28.—*Apanteles thompsoni adults released in the United States through December 31, 1940—Con.*

[All parasites released were from Europe except where indicated]

State and County	Township	1926	1927	1928	1929	1930	1931	1932	Total[1]
Rhode Island:[6]									
Newport	Portsmouth	0	0	0	0	0	0	0	10
Providence	E. Providence	0	0	7,177	303	0	4,266	0	11,746
Total		0	0	7,177	303	0	4,266	0	11,756
Total, United States		2,936	34,680	88,139	16,180	5,459	49,028	51,731	252,085

[1] The totals in this column include the numbers given in the footnotes to this table.

[2] In 1925, 727 adults were liberated in Arlington Township, Middlesex County, and 1,675 in Medford Township, Middlesex County.

[3] Includes 5 laboratory-bred specimens.

[4] In 1933, 126 adults were liberated in Southold Township, Suffolk County.

[5] In 1925, 1,075 adults were liberated in Perkins Township, Erie County and in 1933, 319 adults were liberated in Perry Township, Wood County.

[6] In 1933, 10 adults were liberated in Portsmouth Township, Newport County.

of laying several eggs in one host in so many instances as to exclude the occurrence from being a matter of chance. Such superparasitization results in the death of all or all but one of the parasites in a single host. The most important factor disclosed by these field-cage studies, and one that possibly has a considerable bearing on the failure of the parasite to become established on *Pyrausta nubilalis,* was the apparent incompatibility of the parasite with the host larvae that were prevalent near the western shore of Lake Erie.

Oviposition was readily obtained in the field cages, but in many cages the eggs failed to hatch, even when only one was deposited per host. Of those that did hatch, almost all the larvae died in the first instar. Only a few live parasite larvae in the second instar have been recorded. Although parasitization as high as 33 percent (as found by dissection) of the hosts was accomplished, no adult parasite was ever produced. It seems possible that some

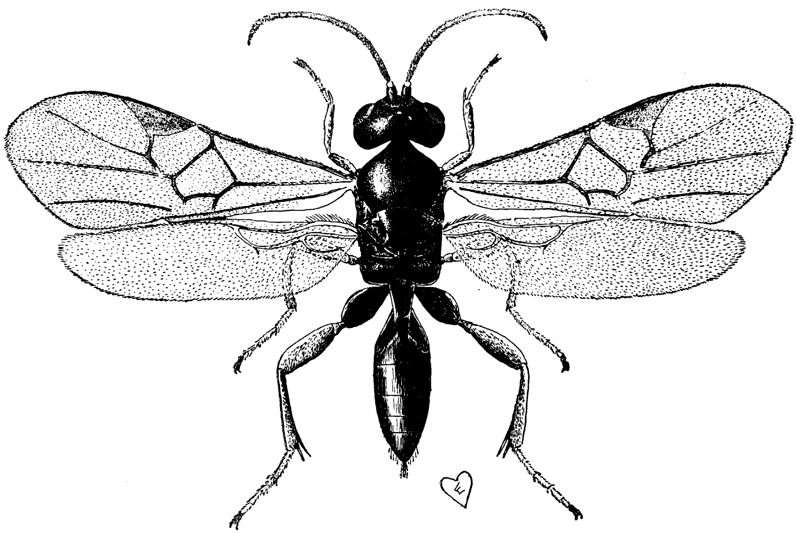

FIGURE 31.—*Apanteles thompsoni,* adult female. × 25.

enzymic action was present, or possibly some necessary hormone was lacking in the borers of the Lake States area, which inhibited development of the immature parasite stages.

If such incompatibility of host and parasite is the limiting factor, further releases in the area already tested would be destined to failure. No liberations have been made in the infested area south of New York.

It is possible that the restricting factor or factors that would permit successful establishment may be absent in New Jersey or southward.

APANTELES THOMPSONI Lyle (Fig. 31)

Order: Hymenoptera.
Family: Braconidae.
Imported from: Northern France (a few from Japan).

Preferred host stage: Second-, third-, and fourth-instar larvae.

Method of parasitization: Deposits eggs freely in body cavity of host. Deposits 20–25 eggs at a single thrust of the ovipositor.

Hibernation: Partly grown first-instar larvae within body of host.

Apanteles thompsoni is a thelyotokous, gregarious braconid parasite which occurs in Europe only in regions where the European corn borer has but one generation. The results of a study of this parasite in Europe have been presented by Vance (*39*).

COLONIZATION

Apanteles thompsoni was first released in the United States at Medford and Arlington, Mass., in 1925 and was imported and liberated each year from 1925 through 1933.

In 1927 it was imported in particularly large numbers and was released for the first time in the Lake States area. Liberations in this area continued through 1932. Data on the United States releases of *Apanteles thompsoni* are given in table 28.

Because this parasite reproduces without fertilization by the male, and produces numerous offspring from a single host, it was thought to be an ideal species for laboratory reproduction. However, attempts to obtain adults for liberation by laboratory rearing proved discouraging. Only a small number of the hosts exposed for parasitization produced parasites and the number of parasites per host, under conditions of mass production, was low. Only five adults from this source were released.

FIELD STATUS

Apanteles thompsoni has been recovered in the United States only at Saugus, Mass. A single parasitized host larva was taken in the fall of 1927 following a release of over 5,000 individuals at that point during the current year. The reason for the failure of this parasite to become established is not known. Its thelyotokous type of reproduction eliminates mating failure as a factor in establishment. It has been tested under diverse environmental conditions in areas where the life cycle of the host approximates that of the species in the region of its origin. It has not been tested in the more southern range of the borer in the United States but, since it is restricted to the 1-generation areas of the host in Europe, it seems unlikely that success would follow its introduction into warmer parts of the infested area.

APANTELES SP.

Order: Hymenoptera.

Family: Braconidae.

Imported from: Japan.

During the season of 1929 a braconid parasite, closely resembling, morphologically, the gregarious parasite *Apanteles thompsoni,* emerged from hosts imported from Japan. Unlike the European species, however, males were present. In 1931 and

1932 this parasite appeared again in small numbers from imported oriental material. A few small colonies (table 29) have been released in the United States. The species has never been recovered.

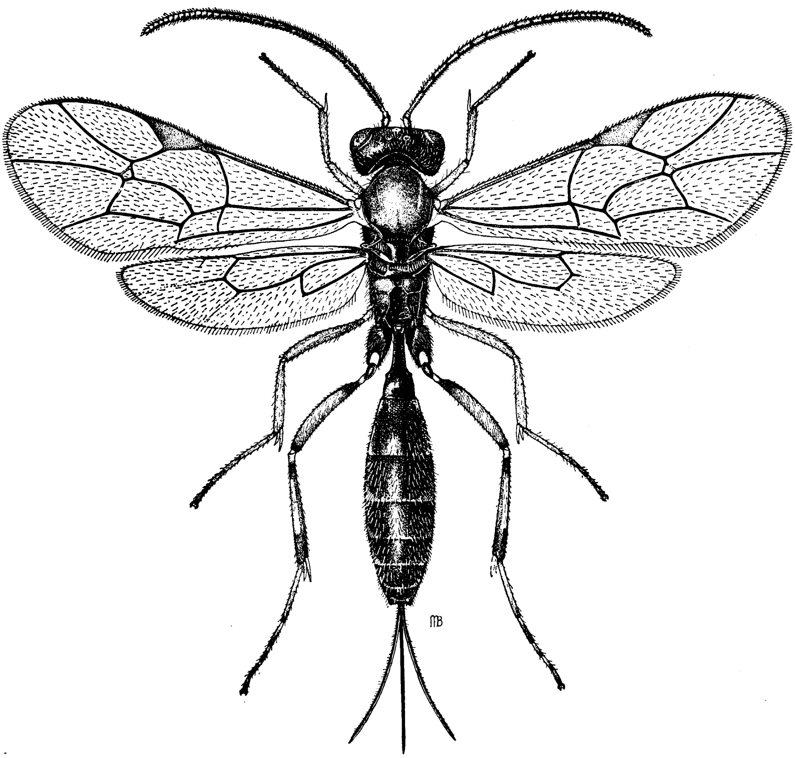

FIGURE 32.—*Campoplex multicinctus*, adult female. × 12.

TABLE 29.—*Numbers of Apanteles sp. adults released in the United States*

State and County	Township	1929	1931	1932	Total
Massachusetts:					
Bristol	Swansea	30	0	0	30
Essex	Saugus	0	78	0	78
Plymouth	Bridgewater	0	93	187	280
Total		30	171	187	388
New York: Schenectady	Glenville	3	0	0	3
Total, United States		33	171	187	391

CAMPOPLEX MULTICINCTUS Grav. (Fig. 32)

Order: Hymenoptera.
Family: Ichneumonidae.
Imported from: France.
Preferred host stage: Probably small larvae.
Method of parasitization: Egg deposited probably directly into body of immature host larvae.
Hibernation: Larva in cocoon.

Among the cocoons of *Campoplex alkae* and *Microgaster tibialis* imported from Paris, France, there appeared a small number of cocoons similar in coloration to those of *C. alkae* but slightly smaller in length and diameter and less dense in texture. From such cocoons there emerged two species of campoplegine parasites, *Campoplex multicinctus and C. pyraustae,* bearing a close resemblance to each other.

The chief diagnostic character for distinguishing between these two species lies in the thoracic carinae. In *Campoplex multicinctus* the median carinae are complete. The appearance of the thoracic sculpturing of the two species is shown in figure 33.

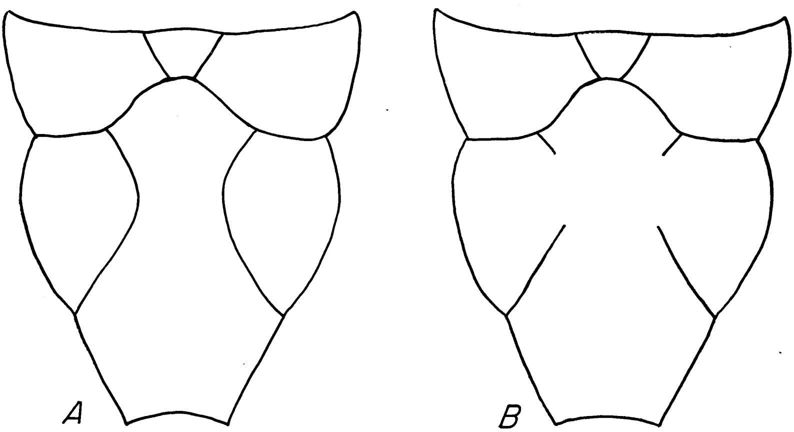

FIGURE 33.—Dorsal view of propodia of parasite larvae, showing character of medium carinae: *A*, *Campoplex multicinctus; B*, *C. pyraustae.*

Campoplex multicinctus was originally described in 1829. A few specimens of it were obtained each year from 1927 to 1933, inclusive, with the exception of 1931. Data on the releases of this species are given in table 30.

As in the case of other parasites imported in the cocoon stage, a number of hyperparasites are associated with *Campoplex multicinctus.* Chief among these are *Scambus nigricans* (Thomson). *Gelis fraudulentus* (Foerst), *Gelis* sp., and an undetermined chalcidoid.

One individual of this species was recovered from a collection of borers taken in the summer of 1927 at Woburn, Mass., following releases made early that year in neighboring towns.

TABLE 30.—*Numbers of Campoplex multicinctus adults released from Europe in the United States, through December 31, 1940*

State and County	Township	1927	1929	1930	1932	Total[1]
Massachusetts:[2]						
Barnstable	Falmouth	0	17	0	0	22
Bristol	Swansea	0	15	0	22	37
Essex	Saugus	114	103	239	0	456
Middlesex	Arlington	94	0	230	3	570
Do	Concord	0	0	0	22	22
Do	Medford	12	0	0	0	12
Suffolk	Revere	10	0	0	0	10
Total		230	135	474	47	1,129
New York:[3]						
Schenectady	Glenville	0	26	0	0	26
Suffolk	Southold	0	0	0	0	35
Total		0	26	0	0	61
Ohio: Lucas	Jerusalem	0	0	357	0	357
Rhode Island:[4]						
Newport	Portsmouth	0	0	0	0	49
Providence	E. Providence	0	74	0	0	74
Total		0	74	0	0	123
Total, United States		230	235	831	47	1,670

[1] The totals in this column include the numbers given in the footnotes to this table.
[2] In 1928, 243 adults were released in Arlington Township, Middlesex County.
[3] In 1933, 35 adults were released in Southold Township, Suffolk County.
[4] In 1933, 49 adults were released in Portsmouth Township, Newport County.

CAMPOPLEX PYRAUSTAE Smith (Fig. 34)

Order: Hymenoptera.
Family: Ichneumonidae.
Imported from: France.
Preferred host stage: Probably small larvae.
Method of parasitization: Egg probably deposited directly into body of host larva.
Hibernation: Mature larva in cocoon.

This is another of the campoplegine parasites that appeared among collections of *Campoplex alkae* and *Microgaster tibialis* cocoons collected in the vicinity of Paris, France. Following its discovery as a parasite of *Pyrausta nubilalis,* it was described as a new species by Smith (*31*). Its importation and colonization in the United States parallels closely that of *Campoplex multicinctus.* Liberation data for *C. pyraustae* are given in table 31.

TABLE 31.—*Numbers of Campoplex pyraustae adults released in the United States, through December 31, 1940*

State and County	Township	1927	1929	1930	1932	Total[1]
Connecticut:						
New London	East Lyme	0	1	0	0	1
Massachusetts:[2]						
Barnstable	Falmouth	0	2	0	0	2
Bristol	Swansea	0	5	0	16	21
Essex	Saugus	0	176	113	0	289
Middlesex	Arlington	258	0	125	7	1,293
Do	Concord	0	0	0	18	18
Do	Medford	47	0	0	0	47
Norfolk	Quincy	0	7	0	0	7
Suffolk	Revere	20	0	0	0	20
Total		325	190	238	41	1,697
New York:[3]						
Schenectady	Glenville	0	4	0	0	4
Suffolk	Southold	0	0	0	0	12
Total		0	4	0	0	16
Ohio: Lucas	Jerusalem	0	0	38	0	38
Rhode Island:[4]						
Newport	Portsmouth	0	0	0	0	24
Providence	E. Providence	0	23	0	0	23
Total		0	23	0	0	47
Total, United States		325	218	276	41	1,799

[1] The totals in this column include the numbers given in the footnotes to this table.
[2] In 1928, 903 adults were released in Arlington Township, Middlesex County.
[3] In 1933, 12 adults were released in Southold Township, Suffolk County.
[4] In 1933, 24 adults were released in Portsmouth Township, Newport County.

One individual of this species was reared from a collection of corn borers taken in the summer of 1929 at Quincy, Mass., following a release of seven individuals of the species at that colony site earlier in the year.

BRACON ATRICORNIS (Smith) (Fig. 35)

Order: Hymenoptera.
Family: Braconidae.
Imported from: France and Japan.
Preferred host stage: Probably small larvae.
Method of parasitization: Probably deposits egg directly into body cavity of host.
Hibernation: Within mature host larva.

Bracon atricornis was described by Smith (*30*) under the name *Agathis atricornis.* Material imported into the United States originated in central France, northern Italy, and southern Japan. Only a few adults of this parasite were obtained from host larvae from either country. With the exception of a release of 183 individuals in 1933 at Newport, R. I., all colonies consisted of less than 50 adults. None were liberated in the Lake States area. The releases in the United States are given in table 32.

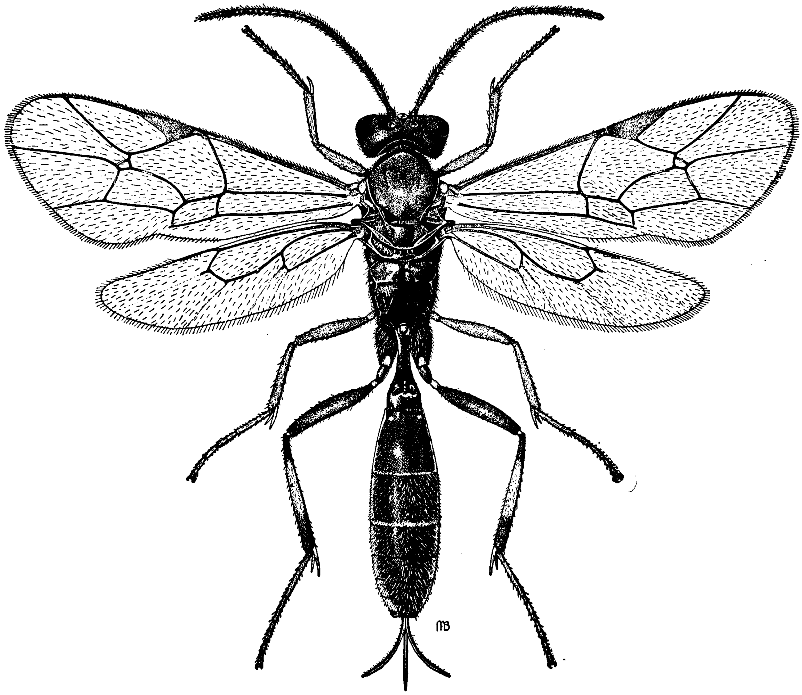

FIGURE 34.—*Campoplex pyraustae,* adult female. × 13.

This species has never been recovered in the United States.

Since gravid females will oviposit readily in young feeding borers in the laboratory, the reason for the failure of *Bracon atricornis* to show even initial establishment was probably due to the small size of the colonies.

METEORUS NIGRICOLLIS Thoms. (Fig. 36)

Order: Hymenoptera.
Family: Braconidae.
Imported from: Northern France.
Preferred host stage: Third-, fourth-, and fifth-stage larvae.
Method of parasitization: Single egg laid free in body cavity of host larva.
Hibernation: In cocoon.

TABLE 32.—*Numbers of Bracon atricornis adults released in the United States, through December 31, 1940*

[All parasites originated in the Orient except where indicated]

State and County	Township	1929	1930	1931	1932	1933	1934	1935	Total
Connecticut: Hartford	E. Hartford	0	0	0	0	0	5	7	12
Massachusetts:									
Essex	Peabody	0	0	0	8	0	0	0	8
Do	Saugus	48	20	0	0	0	0	0	68
Do	do[1]	0	8	0	0	0	0	0	8
Middlesex	Arlington	0	0	0	2	0	0	0	2
Do	Concord	0	0	0	0	0	4	0	4
Do	Medford	0	0	0	27	0	0	0	27
Do	do[1]	0	0	0	6	0	0	0	6
Plymouth	Bridgewater	0	0	4	0	0	0	0	4
Total		48	28	4	43	0	4	0	127
Rhode Island:									
Newport	Portsmouth	0	0	0	18	183	0	0	201
Do	do[1]	0	0	0	0	10	0	0	10
Total		0	0	0	18	193	0	0	211
Total, United States		48	28	4	61	193	9	7	350

[1] From Europe.

A colony of 8 adults of *Meteorus nigricollis* was released at Newport, R. I., in 1933. Since this represents the entire quantity made available for release in the United States from the considerable amount of host material observed in the country of its origin, its unimportance as a European corn borer parasite is readily appreciated. Notes on the biology and morphology of this parasite, as ascertained from the study of a small number of individuals associated with the European corn borer in France, have been published by Parker (*25*). The 8 adults released at

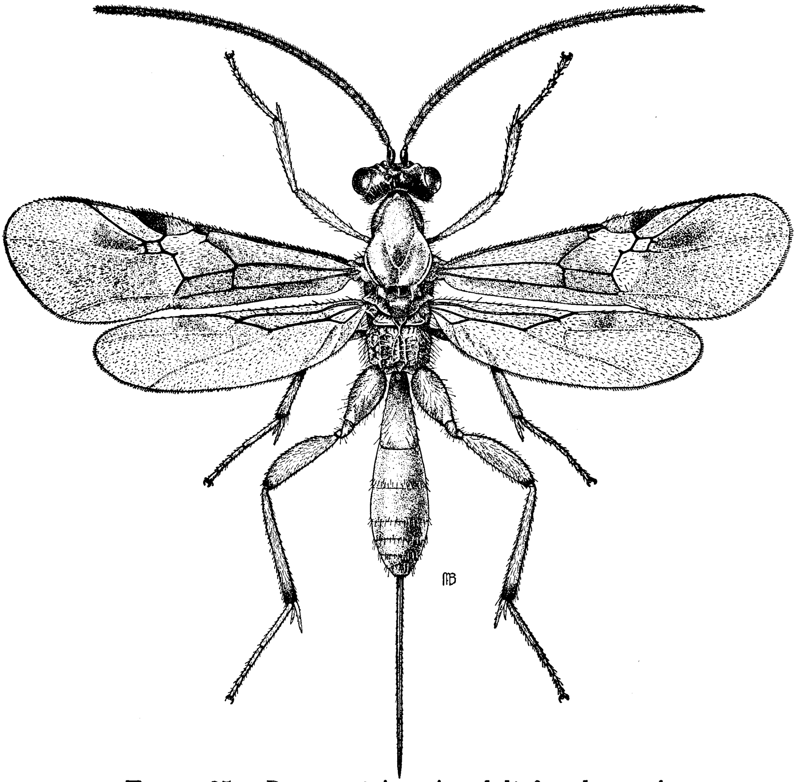

FIGURE 35.—*Bracon atricornis*, adult female. × 4.

Newport were obtained from 68 cocoons received from Europe in the spring of 1933, and no recoveries of this species have been made in the United States.

APLOMYA MITIS (Meig.)

Order: Diptera.
Family: Larvaevoridae.
Imported from: Europe.
Preferred host stage: Probably from small larvae to fourth instar.
Method of parasitization: Probably deposits mature eggs or living larvae.
Hibernation: Small larvae within mature host larvae.

From the imported host larvae received in the winter of 1927–28 from the vicinity of Paris, France, there emerged a small number of larvaevorids, similar in general appearance to *Lydella stabulans grisescens,* but having hairy eyes. This hairy-eyed species was introduced under the name *Zenillia mitis* Meig., but at that time no difference in morphology or coloration was found between it and the widely distributed *Aplomya caesar,* which is native to the United States.

Importations of small numbers of this parasite were made annually from 1928 through 1933, inclusive, and small colonies were released each year in both the Eastern States and Lake States areas. The largest colony was liberated in Jerusalem Township, Lucas County, Ohio, in 1930. Releases of the species in the United States are given in table 33.

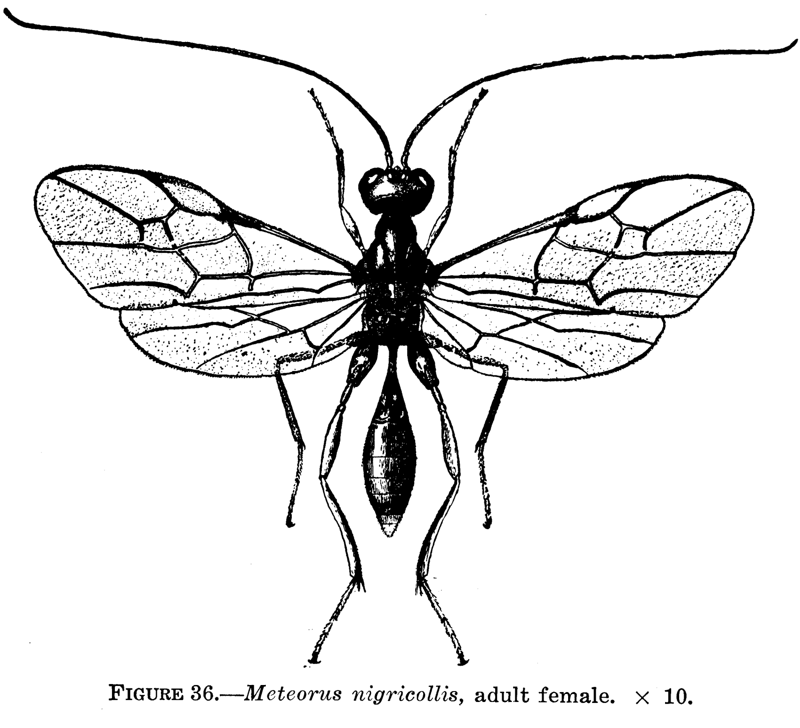

FIGURE 36.—*Meteorus nigricollis,* adult female. × 10.

The confusion that existed regarding the identity of *Aplomya mitis* with *A. caesar* has, in the past, made accurate recovery records impossible. An examination of the data relative to recovery of larvaevorids conforming to the description of either *A. mitis* or *A. caesar* shows that such flies have been recovered in nearly equal numbers from localities far removed from colony sites of *A. mitis,* or in collections made prior to the introduction of *A. mitis,* as from localities in the vicinity of points where *A. mitis* had been released. However, Wendell Sellers has recently completed a study of the genus and has found a diagnostic character by which the European species may be distinguished from

the form native to the United States. In *A. mitis,* the species imported from Europe, the parafrontals are silvery-smoky, whereas in *A. caesar,* the species indigenous to the United States, they are tawny-brassy. Mr. Sellers' research in connection with the genus led him to believe that none of the flies recovered in the United States belong to the species *A. mitis.*

PSEUDOPERICHAETA ROSEANAE (B. & B.) (Fig. 37)

Order: Diptera.
Family: Larvaevoridae.
Imported from: Europe.
Method of parasitization: Fully developed eggs deposited on or near host.

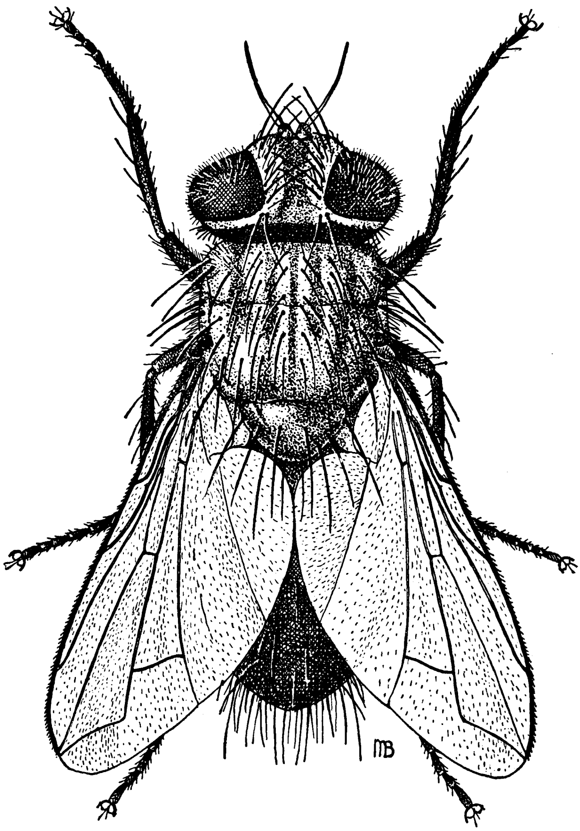

FIGURE 37.—*Pseudoperichaeta roseanae,* adult female. × 9.

Preferred host stage: Probably middle larval instars.
Hibernation: Larva within mature host larva.

The morphology of the immature stages and of the adult *Pseudoperichaeta roseanae* and a brief account of its biology as a parasite of the European corn borer in Europe, have been published by Thompson and Thompson (*36*).

TABLE 33.—*Numbers of Aplomya mitis adults released from Europe in the United States, through December 31, 1940*

State and County	Township	1928	1929	1930	1931	1932	1933	Total
Connecticut: New London	East Lyme	18	3	140	14	3	0	178
Indiana: Steuben	York	0	8	0	0	0	0	8
Massachusetts:								
Barnstable	Falmouth	9	0	130	60	0	0	199
Bristol	Swansea	0	5	0	0	3	0	8
Essex	Saugus	0	0	39	3	0	0	42
Middlesex	Arlington	176	0	0	5	2	0	183
Norfolk	Quincy	82	0	0	0	0	0	82
Total		267	5	169	68	5	0	514
Michigan:								
Monroe	Monroe	0	10	0	0	0	0	10
St. Clair	Columbus	0	0	385	0	0	0	385
Total		0	10	385	0	0	0	395
New York:								
Cattaraugus Indian Res.		0	16	0	0	0	0	16
Erie	Lancaster	0	1	0	0	0	0	1
Schenectady	Glenville	0	0	347	0	0	0	347
Suffolk	Southold	0	0	0	0	0	99	99
Total		0	17	347	0	0	99	463

Ohio:								
Henry	Damascus	0	0	96	38	47	0	181
Lucas	Jerusalem	0	5	1,328	93	0	0	1,426
Wood	Perry	0	0	0	0	0	57	57
Total		0	5	1,424	131	47	57	1,664
Pennsylvania: Erie	Harbor Creek	0	20	0	0	0	0	20
Rhode Island:								
Newport	Portsmouth	0	0	0	0	4	4	8
Providence	E. Providence	0	15	120	45	0	0	180
Total		0	15	120	45	4	4	188
Total, United States		285	83	2,585	258	59	160	3,430

TABLE 34.—*Numbers of Pseudoperichaeta roseanae adults released in the United States through December 31, 1940*

[All parasites from Europe except where indicated]

State and County	Township	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	Total[1]
Connecticut:												
Hartford	E. Hartford	0	0	0	0	0	0	0	0	0	2,280	2,280
New London	East Lyme	0	0	0	0	557	2,359	152	2,406	0	0	5,474
Total		0	0	0	0	557	2,359	152	2,406	0	2,280	7,754
Indiana: Steuben	York	0	0	0	0	4,956	1,793	1,777	0	0	0	8,526
Massachusetts:[2]												
Barnstable	Falmouth	0	0	0	717	4,409	654	2,630	0	0	0	8,410
Bristol	Swansea	0	0	0	30	1,974	0	0	775	0	0	2,779
Do	do[3]	0	0	0	0	0	0	0	878	0	0	878
Essex	Peabody	0	0	0	0	0	0	0	12	0	0	12
Do	Saugus	0	215	5,732	0	1	88	1,799	0	0	0	7,835
Middlesex	Arlington	101	177	8,784	241	0	0	0	0	0	0	9,303
Do	Concord	0	0	0	0	0	0	0	4,607	0	47	4,654
Do	Malden	197	87	6,357	0	0	0	0	0	0	0	7,481
Do	Medford	361	2,775	7,297	0	0	0	0	0	0	0	10,433
Do	Watertown	0	0	0	0	0	0	0	0	0	0	94
Norfolk	Quincy	0	0	2,849	1,995	0	0	0	0	0	0	4,844
Suffolk	Revere	0	0	8,079	0	0	0	0	0	0	0	8,079
Total		659	3,254	39,098	2,983	6,384	742	4,429	6,272	0	47	64,802
Michigan:												
Lenawee	Fairfield	0	0	0	0	0	1,375	0	1,853	0	0	3,228
Monroe	Erie	0	0	3,278	0	0	0	0	298	0	0	3,576
Do	Monroe	0	0	0	1,803	1,784	0	0	0	0	0	3,587
St. Clair	Columbus	0	0	0	31	3,943	2,050	0	1,481	0	0	7,505
Total		0	0	3,278	1,834	5,727	3,425	0	3,632	0	0	17,896

New York:												
Cattaraugus Indian Res.		0	0	0	5,714	14,127	1,975	0	0	0	0	21,816
Chautauqua	Portland	0	0	0	589	0	0	0	0	0	0	589
Do	Westfield	0	0	0	86	0	0	0	0	0	0	86
Erie	Lancaster	0	0	0	0	501	0	0	0	0	0	501
Jefferson	Adams	0	0	0	0	0	0	1,715	332	0	0	2,047
Schenectady	Glenville	0	0	0	0	4,572	0	0	0	0	0	4,572
Suffolk	Southold	0	0	0	0	0	0	0	0	45	0	45
Do	do[3]	0	0	0	0	0	0	0	0	87	0	87
Total		0	0	0	6,389	19,200	1,975	1,715	332	132	0	29,743
Ohio:												
Erie	Perkins	0	0	556	97	0	0	0	0	0	0	653
Hancock	Marion	0	0	0	0	0	0	0	2,099	0	0	2,099
Henry	Damascus	0	0	0	0	0	4,978	5,089	6,112	0	0	16,179
Lake	Mentor	0	0	0	196	0	0	0	0	0	0	196
Lucas	Jerusalem	0	0	59	816	5,682	2,040	2,780	0	0	0	11,377
Putnam	Jennings	0	0	0	0	0	0	0	1,773	0	0	1,773
Wood	Perry	0	0	0	0	0	0	0	0	48	0	48
Do	do[3]	0	0	0	0	0	0	0	0	9	0	9
Total		0	0	615	1,109	5,682	7,018	7,869	9,984	57	0	32,334
Pennsylvania:												
Crawford	Greenwood	0	0	0	0	13	0	0	0	0	0	13
Erie	Harbor Creek	0	0	0	0	3,787	0	0	0	0	0	3,787
Total		0	0	0	0	3,800	0	0	0	0	0	3,800

TABLE 34.—*Pseudoperichaeta roseanae adults released in the United States through December 31, 1940—Con.*

[All parasites from Europe except where indicated]

State and County	Township	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	Total[1]
Rhode Island:												
Newport	Portsmouth	0	0	0	0	0	0	0	25	15	0	40
Do	do[3]	0	0	0	0	0	0	0	618	69	0	687
Providence	E. Providence	0	0	0	1,036	4,270	24	3,248	0	0	0	8,578
Total		0	0	0	1,036	4,270	24	3,248	643	84	0	9,305
Total, United States		659	3,254	42,991	13,351	50,576	17,336	19,190	23,269	273	2,327	174,160

[1] The totals in this column include the numbers given in the footnotes to this table.

[2] In 1920, 94 were released in Watertown Township, Middlesex County; in 1921, 784 were released in Malden Township, Middlesex County; and in 1922, 56 were released in the latter Township.

[3] Of domesic origin.

COLONIZATION

This larvaevorid was one of the first three species to be imported, a small colony being liberated at Watertown, Mass., in 1920.

The species was imported annually from 1920 through 1934, except in 1923 and 1924. Releases were made in the Lake States area in 1927–33. Colonization data for this species are given in table 34.

The earliest importations were made in the summer with the parasite in the pupal stage. The great bulk of the imported material, however, was received as immature larvae within hibernating host larvae shipped during the winter months. A few adults were obtained from northern Italy and from the area around Paris, France, but most of the imported material came from southern France.

FIELD STATUS

Pseudoperichaeta roseanae is another of the imported larvaevorid parasites which has been confused with a species indigenous to the United States, being indistinguishable, morphologically, from *P. erecta* (Coq.). Accuracy of recovery records, therefore, relative to *P. roseanae* has been impossible, and it is regarded as never having been established. However, unlike the evidence that suggests the probable nonestablishment of the equally confusing larvaevorid *Aplomya mitis,* there is some indication that initial establishment at least followed the introduction of *P. roseanae* at certain points.

From the year 1927, when general collections to determine the status of corn borer parasites were first begun, a larvaevorid conforming to the description of *Pseudoperichaeta roseanae* was obtained yearly from most of the locations examined in eastern New England. In 1927 and 1928 these recoveries indicated a parasitization no greater than 1 percent at any of the locations observed, whether near release points or otherwise. In the summer of 1929, however, a season in which certain other imported parasites of the corn borer showed a noticeable increase, parasitization by this larvaevorid throughout eastern Massachusetts was generally higher than in the two previous years, with two of the collections showing concentrations higher than 17 percent. In the summer of 1932, 2,300 adults of this larvaevorid were recovered from a large amount of host plant material, which produced 7,400 adults of *Horogenes punctorius* but only 1,600 adults of *Lydella stabulans grisescens.* While such concentrations do not conclusively demonstrate the establishment of *P. roseanae,* they indicate the presence of some factor, such as the introduction of a foreign parasite, which exerted a greater augmenting influence than could be expected from the normal concentrations of a native parasite.

Whether or not *Pseudoperichaeta roseanae* ever became established may be open to question, but records of recent years point conclusively to its failure to maintain itself. No recovery of a

larvaevorid resembling *P. roseanae* has been made for a number of years from any collection of European corn borers in the United States.

While parasitization of corn borers by *Pseudoperichaeta roseanae* in most areas in Europe is low, seldom rising above 1 percent, it has reached considerable proportions in certain limited localities. Parker *et al.* (*27*) have noted parasitizations of 24 and 30 percent in the coastal areas of Dalmatia and 11 percent in southwestern France.

Evidence of a favorable potential of the parasite in limited optimum areas, in conjunction with the probability that it is capable of strong initial establishment, suggests the desirability of testing the species further in uncolonized areas.

Nemorilla floralis (Fallen)

Order: Diptera.
Family: Larvaevoridae.
Imported from: The Orient.
Hibernation: Within mature host larva.

In 1932 a few adults of this species issued from larval host material imported from the Orient (Chosen and southern Japan). During this year releases were made as follows: Connecticut 553, Massachusetts 371, and Ohio 843, or a total of 1,747. The species has been recorded as a parasite of the European corn borer in southern France but was not recorded as being imported from that region.

The small number of adults imported reflects the slight importance of the species in the Orient. The species is also indigenous to the United States and for a number of years prior to its introduction from Japan, it had been recorded as generally distributed over eastern New England as a corn borer parasite. Field observations on the species have not suggested any biological difference between the native and imported form.

Pseudoperichaeta erecta (Coq.)

Order: Diptera.
Family: Larvaevoridae.
Imported from: The Orient.
Method of parasitization: Probably deposits fully developed eggs on or near host.
Preferred host stage: Probably middle-instar larvae.
Hibernation: Larva within mature host larva.

The history of the importation of this species is similar to that of *Nemorilla floralis,* adults having been imported only from the Orient and in the years 1932 and 1933. Releases were made as follows: Connecticut 193, Massachusetts 844, New York 4, Ohio 499, or a total of 1,540. All but 12 of these adults were released in 1932.

This species, like *Pseudoperichaeta roseanae,* has been recorded as indigenous to the United States and is indistinguishable morphologically from the latter larvaevorid parasite imported from Europe.

The characters by which the puparia of the four species of larvaevorids imported to the United States may be separated are shown by photographs of the anal stigmata (fig. 38).

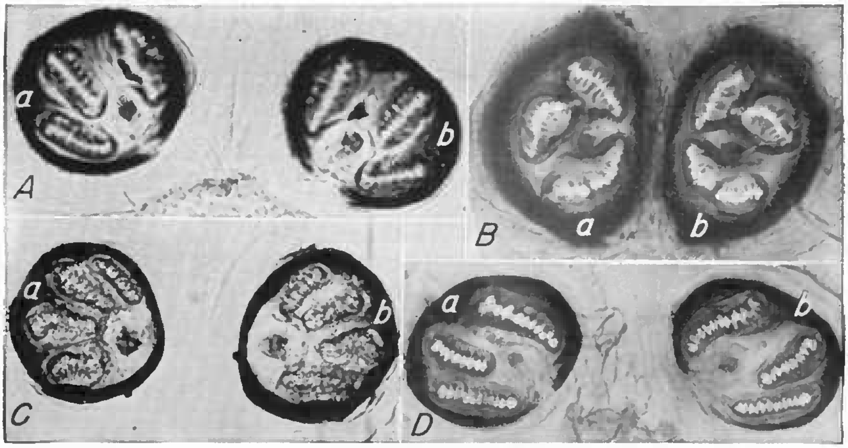

FIGURE 38.—Anal stigmata from the puparia of four larvaevorid parasites of the European corn borer: *A, a, Nemorilla maculosa; b, N. floralis; B, Lydella stabulans grisescens; C, a, Pseudoperichaeta erecta; b, P. roseanae; D, a, Aplomya mitis; b, A. caesar.* × 210.

MICROGASTER TIBIALIS Nees (Fig. 39)

Order: Hymenoptera.
Family: Braconidae.
Imported from: Europe, the Orient.

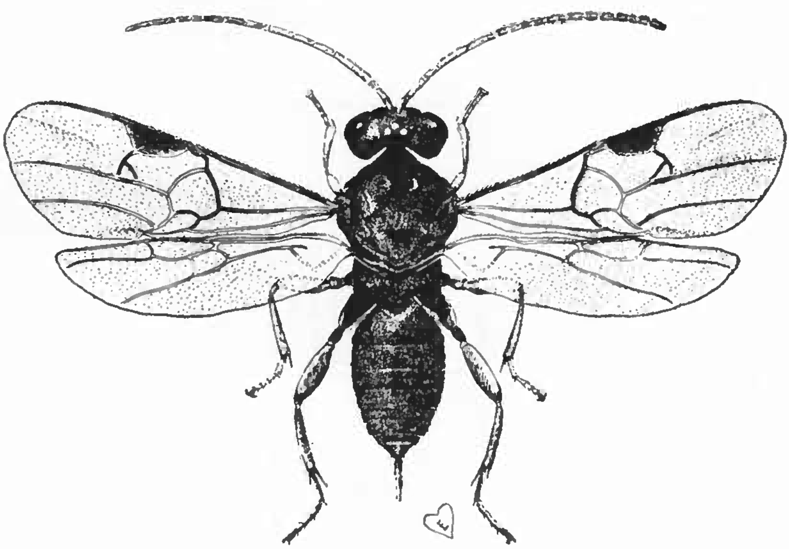

FIGURE 39.—*Microgaster tibialis*, adult female. × 16.

TABLE 35.—*Numbers of Microgaster tibialis adults released in the United States through December 31, 1940*

State and County	Township	Origin[1]	1925	1926	1927	1928	1929	1930	1931	1932	1933	1936	Total[2]
Connecticut:													
Hartford	E. Hartford	E	0	0	0	0	0	0	0	0	0	1,994	1,994
New London	E. Lyme	E	0	0	0	3,970	203	852	0	10	0	0	5,035
Do	do	O	0	0	0	0	0	0	0	72	0	0	72
Total			0	0	0	3,970	203	852	0	82	0	1,994	7,101
Indiana: Steuben	York	E	0	0	0	0	2,999	2,006	1,990	1,990	0	0	8,985
Massachusetts:[3]													
Barnstable	Chatham	E	246	0	0	0	0	0	0	0	0	0	246
Do	Falmouth	E	0	0	0	8,743	233	5,105	1,390	0	0	0	15,471
Bristol	Dighton	E	0	0	0	0	13	0	0	0	0	0	13
Do	Swansea	E	0	0	0	0	154	0	0	20	0	0	174
Essex	Saugus	E	357	1,314	6,303	0	0	287	236	0	0	0	8,497
Do	do	O	0	0	0	0	0	0	121	0	0	0	121
Middlesex	Arlington	E	2,418	2,075	5,590	1,969	0	0	0	0	0	0	12,507
Do	do	B	0	0	0	1,478	0	0	0	0	0	0	2,678
Do	Concord	E	0	0	0	0	0	0	0	1,832	0	0	1,832
Do	Malden	E	1,446	2,134	5,659	0	0	0	0	0	0	0	9,239
Do	Medford	E	1,093	5,005	5,754	0	0	0	0	0	0	0	11,852
Norfolk	Quincy	E	0	0	5,740	5,451	0	0	0	0	0	0	11,191
Do	do	B	0	0	0	830	0	0	0	0	0	0	830
Plymouth	Bridgewater	O	0	0	0	0	0	0	237	1,046	0	0	1,283
Suffolk	Revere	E	0	1,748	7,007	0	0	0	0	0	0	0	8,755
Total			5,560	12,276	36,053	18,471	400	5,392	1,984	2,898	0	0	84,683

Michigan:													
Lenawee	Fairfield	E	0	0	0	0	1,978	2,732	0	0	0	0	4,710
Monroe	Erie	E	0	0	8,631	12,117	1,897	0	0	681	0	0	23,316
Do	Monroe	E	0	0	2,275	12,391	1,575	2,075	1,530	1,504	0	0	21,350
Oakland	Oxford	E	0	0	0	0	1,970	1,989	0	0	0	0	3,959
St. Clair	Columbus	E	0	0	5,711	11,395	2,585	4,994	1,962	0	0	0	26,647
Washtenaw	Augusta	E	0	0	0	0	1,765	0	0	0	0	0	1,765
Total			0	0	16,617	35,903	11,860	11,790	3,492	2,085	0	0	81,747
New Jersey:													
Monmouth	Atlantic	E	0	0	0	0	0	0	0	0	0	1,809	1,809
New York:													
Cattaraugus Indian Res.		E	0	0	995	4	9,931	1,999	0	0	0	0	12,929
Chautauqua	Portland	E	0	0	0	0	0	1,827	0	0	0	0	1,827
Erie	Lancaster	E	0	0	0	0	8,950	0	0	0	0	0	8,950
Jefferson	Adams	E	0	0	0	0	0	1,992	2,200	1,944	0	0	6,136
Schenectady	Glenville	E	0	0	0	0	35	2,071	0	0	0	0	2,106
Suffolk	Southold	E	0	0	0	0	0	0	0	0	2,804	0	2,804
Total			0	0	995	4	18,916	7,889	2,200	1,944	2,804	0	34,752
Ohio:													
Erie	Perkins	E	1,296	1,002	10,303	13,202	0	0	0	0	0	0	25,803
Hancock	Marion	E	0	0	0	0	1,990	1,998	0	0	0	0	3,988
Henry	Damascus	E	0	0	0	0	0	9,558	4,949	4,525	0	0	19,032
Huron	Richmond	E	0	0	0	0	3,000	1,985	0	0	0	0	4,985
Lake	Mentor	E	0	2,725	9,853	9,316	1,946	0	0	0	0	0	23,840
Lucas	Jerusalem	E	0	4,565	11,447	13,186	2,822	4,962	2,585	0	0	0	39,567
Summit	Northampton	E	0	0	0	0	2,990	1,976	0	0	0	0	4,966
Wood	Perry	E	0	0	0	0	0	0	0	0	16,404	0	16,404
Total			1,296	8,292	31,603	35,704	12,748	20,479	7,534	4,525	16,404	0	138,585

TABLE 35.—*Microgaster tibialis adults released in the United States through December 31, 1940*—*Con.*

State and County	Township	Origin[1]	1925	1926	1927	1928	1929	1930	1931	1932	1933	1936	Total[2]
Pennsylvania:													
Crawford	Greenwood	E	0	0	0	0	403	0	0	0	0	0	403
Erie	Harbor Creek	E	0	0	0	9	4,461	1,969	0	0	0	0	6,439
Total			0	0	0	9	4,864	1,969	0	0	0	0	6,842
Rhode Island:													
Newport	Portsmouth	E	0	0	0	0	0	0	0	0	1	0	1
Providence	E. Providence	E	0	0	0	7,616	484	9,469	2,170	0	0	0	19,739
Total			0	0	0	7,616	484	9,469	2,170	0	1	0	19,740
Virginia:													
Accomac	Lee	E	0	0	0	0	0	0	0	0	0	2,093	2,093
Northampton	Franktown	E	0	0	0	0	0	0	0	0	0	1,106	1,106
Total			0	0	0	0	0	0	0	0	0	3,199	3,199
Total, United States			6,856	20,568	85,268	101,677	52,480	59,846	19,370	13,524	19,209	7,002	387,443

[1] B, Bred in the laboratory; E, from Europe; O, from the Orient.

[2] The totals in this column include the numbers given in footnotes to this table.

[3] In 1924, 449 parasites from Europe and 1,200 parasitized borers were released in Arlington Township, Middlesex County.

Method of parasitization: Deposits eggs singly, free in body cavity of host.

Preferred stage: Second- and third-instar borers.

Hibernation: As a prepupa in cocoon.

The results of a study of this species as a parasite of *Pyrausta nubilalis* in Europe have been published by Vance (*41*).

COLONIZATION

Microgaster tibialis occurs in Europe and the Orient in areas having both one and two generations of the host. In each region, however, it is more abundant in the northern range of the borer. Shipments from Europe were chiefly from the vicinity of Paris, France, but some material was obtained in southwestern France and northern Italy. The first importations were made from Europe during the winter of 1923–24, and yearly importations from this source continued through 1933. In 1935–36 further importations were made from Europe, to provide material for releases in untested areas, chiefly south of New York.

Releases in the Lake States area were first made in 1927 and continued yearly through 1933. Only adults originating in Europe were released in the Lake States.

In 1931 and 1932 a small number of cocoons from Chosen were imported and the adults that hatched therefrom were released at Saugus and Bridgewater, Mass.

When adults of this species were first obtained in 1924, attempts were made to rear material in the laboratory for liberation. A trial was made of reproducing the species by placing larvae that had been exposed to parasitization on growing plants in a greenhouse. Practically no adults could be obtained by this method and the technique described by Jones (*18*) proved to be the most productive. As a result of this laboratory rearing, a small number of host larvae that had been exposed to parasitization were placed on infested plants in the field in 1924, and in 1928 a number of adults obtained by rearing were liberated in eastern Massachusetts.

In that year over 25,000 host larvae were exposed to parasitization in the laboratory, but of this number only 21 percent produced parasites. Records kept during the production period showed that the best results were obtained between July 1 and August 15, and that earlier and later rearing activity was much less productive. The parasitization of the host larvae and their subsequent rearing until parasite cocoons were produced involved considerable time and labor and, because of the small number of cocoons obtained per unit number of host larvae exposed for parasitization, it was found to be more economical to import material for colonization than to rear it. The liberations in the United States of adults from all sources are shown in table 35.

When studying the life history of *Microgaster tibialis* in Europe, the writers noted that the seasonal rhythm of the parasite did not synchronize with that of its host, the parasite adults appearing in the spring in the colder areas, far in advance of their host. When held under natural environmental conditions in the United States, imported cocoons also produced adults at

a time when no hosts were present in the field, and releases from such material produced no establishment. Methods utilized in correcting this situation and the results obtained have been published by Baker and Arbuthnot (*1*).

FIELD STATUS

Following a release of 449 adults of *Microgaster tibialis* in the spring of 1924 at Arlington, Mass., the species was recovered near the release point in the fall of that year.

Recoveries were recorded in Massachusetts in several subsequent years, but only at points where current releases had been made. With the cessation of supporting releases the parasite was no longer recovered.

The field status of the species in the Lake States has been reviewed by Baker and Arbuthnot (*1*), who state that recovery collections "failed in every instance to show this parasite present except in those localities where current synchronized liberations were also made."

Two chief factors, one contingent on the other, stand out as an explanation of the failure of *Microgaster tibialis* to survive in the United States.

The habit of the adults of appearing early in the spring, long before their hosts are available in the field, apparently constitutes a disadvantage to the parasite in areas where alternate hosts, by means of which the intervening period may be bridged, are absent.

Evidently alternate hosts, which might serve the purpose of enabling the parasite to survive the period between parasite emergence and the appearance of third-instar borers in the field, are absent from the area in which the parasite has been tested.

In certain localities in Europe *Microgaster tibialis* has shown itself capable of comparatively high concentrations. Vance (*41*) states: "The average parasitism for the eight-year period (1922–1929, inclusive) in the region of Paris, was 29.7 percent, with maximums of 63.2 and 52.5 percent in 1925 and 1926, respectively."

The species is decidedly polyphagous in habit. Thompson and Parker (*34*) note that 14 species of Lepidoptera have been recorded as hosts.

Since its maintenance in the United States appears to be dependent on its ability to find an alternate host, and on the availability of this host, the parasite is apparently incapable of building up to a considerable population. Therefore its further testing in uncolonized regions seems desirable.

LABRORYCHUS SP.

Order: Hymenoptera.
Family: Ichneumonidae.
Imported from: Italy.
Preferred host stage: Probably full-grown larva.
Method of parasitization: Eggs probably oviposited directly into body of host.
Hibernation: Larva within mature host larva.

Fifty-three adults of a species of *Labrorychus* were obtained from the corn borer larvae collected in the vicinity of Pietrasanta, Italy, during the winter of 1934–35. This parasite attacks the host larva, but does not leave it until the host has pupated. Since the individuals obtained during the emergence season of 1935 were the only ones obtained from the thousands of host larvae handled over several years of importations, the parasite was considered of no economic importance and no specific attempts were made to obtain adults for colonization.

PARATHERESIA CLARIPALPIS (V. D. W.)

Order: Diptera.
Family: Larvaevoridae.
Imported from: Peru, South America.

In July 1931, 5,000 puparia of this larvaevorid fly were diverted from a lot of 70,000 being shipped to the United States for use against the sugarcane borer. From the 5,000 cocoons, 1,476 adults were obtained, 1,163 of which were released in Saugus, Mass., and the remainder were tested on *Pyrausta nubilalis* larvae in the laboratory. No specimen of *Paratheresia claripalpis* was recovered and attempts to rear it in the laboratory on *P. nubilalis* were unsuccessful.

PARASITE COMPLEXES AT TEST POINTS IN THE UNITED STATES

Because of the slow increase and spread of all corn borer parasites, equilibrium between the host and parasites has been attained at only one point in the United States, that is, a comparatively small area north and west of Boston, Mass., where the earliest releases were made. At all other points one or more of the parasites present are in the process of change in relationship with the host. A discussion of the parasite complexes as based on recent surveys follows.

MALDEN, MASS.

Malden, Mass., designates a group of release points at which the earliest introduced parasites were liberated. (See Arlington, Cambridge, Concord, Lexington, Malden, Medford, Peabody, Revere, Saugus, Waltham, and Watertown, in the colonization tables.) Exotic parasites are present over an area of at least 177 square miles. The parasites of importance in this locality in 1940 were *Horogenes punctorius, Lydella stabulans grisescens,* and *Phaeogenes nigridens,* and of these *H. punctorius* was predominant. For the overwintering generation of the host, the rate of parasitization seemed to have become stabilized at approximately 14 percent, with an oscillation of plus or minus 3 percent. This parasite status had been maintained over 9 consecutive years (18 generations of the borer). On the summer generation, parasitization averaged considerably higher, the survey of 1938 showing a parasitization of 25.7 percent and that of 1939, 19 percent.

TABLE 36.—*European corn borer parasitization by exotic species in the Taunton, Mass., area, in concentric rings 5 miles wide, fall of 1938*

Area surveyed (rings)	Borers observed	Borers parasitized by—										Total	
		Chelonus annulipes		*Horogenes punctorius*		*Macrocentrus gifuensis*		*Zaleptopygus flavo-orbitalis*		*Lydella stabulans grisescens*			
	Number	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Center	86	0	0	2	2.3	9	10.5	0	0	11	12.8	22	25.6
First	999	31	3.1	18	1.8	121	12.1	0	0	52	5.2	222	22.2
Second	1,739	19	1.1	13	.7	174	10.0	3	0.2	123	7.1	332	19.1
Third	2,652	1	[1]T	3	.1	270	10.2	0	0	88	3.3	362	13.7
Fourth	3,114	1	[1]T	33	1.1	142	4.6	0	0	20	.6	196	6.3
Center and first	1,085	31	2.9	20	1.8	130	12.0	0	0	63	5.8	244	22.5
Center through second	2,824	50	1.8	33	1.2	304	10.8	3	.1	186	6.6	576	20.5
Center through third	5,476	51	.9	36	.7	574	10.5	3	.1	274	5.0	938	17.2
Center through fourth	8,590	52	.6	69	.8	716	8.3	3	[1]T	294	3.4	1,134	13.2

[1] T, Trace—less than 0.1 percent.

TABLE 37.—*Corn borer parasitization by four exotic species in the Taunton, Mass., area at the close of 1937 and 1938*

Section No.	Number borers observed		Percentage of parasitization by—								Total	
			Chelonus annulipes		*Horogenes punctorius*		*Lydella stabulans grisescens*		*Macrocentrus gifuensis*			
	1937	*1938*	*1937*	*1938*	*1937*	*1938*	*1937*	*1938*	*1937*	*1938*	*1937*	*1938*
1	100	86	13.0	0	10.0	2.3	3.0	12.8	0	10.5	26.0	25.6
2–11	914	999	5.1	3.1	1.9	1.8	4.8	5.2	2.2	12.1	14.0	22.2
12–31	1,975	1,739	.8	1.1	.5	.7	2.0	7.1	1.9	10.0	5.2	18.9
32–61	2,755	2,652	[1]T	[1]T	.4	.1	.5	3.3	.9	10.2	1.8	13.7
62–101	3,521	3,114	.1	[1]T	.2	1.1	.4	.6	.2	4.6	.9	6.3
1–11	1,014	1,085	5.9	2.9	2.7	1.8	4.6	5.8	2.0	12.0	15.2	22.5
1–31	2,989	2,824	2.5	1.8	1.2	1.2	2.9	6.6	1.9	10.8	8.5	20.4
1–61	5,744	5,476	1.3	.9	.8	.7	1.7	5.0	1.4	10.5	5.2	17.1
1–101	9,265	8,590	.8	.6	.6	.8	1.2	3.4	1.0	8.3	3.6	13.1

[1] T, Trace—less than 0.1 percent.

TAUNTON, MASS.

This town lies in the approximate center of a 2,000-square-mile area in southeastern Massachusetts influenced by a number of release points including that at Bridgewater, Mass., which was reserved for parasite species of Oriental origin. Other release points in that area are Portsmouth and East Providence, R. I., and Swansea, Falmouth, Quincy, and Dighton, Mass.

The exotic parasite complex in the Taunton locality consists of five species, as follows: *Lydella stabulans grisescens, Horogenes punctorius, Macrocentrus gifuensis, Chelonus annulipes,* and *Zaleptopygus flavo-orbitalis.*

Table 36 gives the borer parasitization by introduced parasites in 5-mile-wide concentric rings in the Taunton area in 1938.

It may be noted from this table that the braconid *Macrocentrus gifuensis* was the most effective parasite, with the larvaevorid *Lydella stabulans grisescens* next in importance. Table 37 shows the comparative abundance of four exotic species in the Taunton, Mass., locality at the close of 1937 and 1938. In the fall of 1937 *L. stabulans grisescens* was the most abundant corn borer parasite but, notwithstanding its considerable increase in 1938, it was overtaken because of the striking increase of *M. gifuensis.* It was estimated that in certain fields in this locality many more parasites than corn borer adults issued in the spring of 1939, and in 1940 the Taunton locality was a more satisfactory source of certain well-established corn borer parasites, particularly *M. gifuensis,* than either the European or the oriental countries from which they were first imported. The increase in 1938 over that of 1937 indicates that equilibrium with the host was not reached prior to 1938. It is also evident that the equilibrium position at Taunton will be characterized by a higher percentage of parasitization than that at Malden.

EAST HARTFORD, CONN.

Horogenes punctorius and *Lydella stabulans grisescens* constitute the exotic parasite complex that is well established on the corn borer in the East Hartford locality. *H. punctorius* is the more important and accounts for most of the parasitization (table 38), not only for the entire area of over 63 square miles but also in each of the concentric districts that make up the area surveyed.

The East Hartford locality provides a particularly favorable release point for the study of the rate and direction of parasite dispersion, because it was one of the earliest in New England to be colonized on the spot-release basis, other release points being sufficiently far removed that their influence would not confuse the records. It is thus significant to note that the percentages of parasitization by *Horogenes punctorius* decreased fairly uniformly as the distance from the center of the locality increased. This graduated decrease showed that the parasite had not nearly reached its equilibrium position for the area as a whole.

Table 39 shows the increase in parasitization of the borer in the central district, a circular area 3 miles in diameter, of the

TABLE 38.—*European corn borer parasitization by exotic species in the East Hartford, Conn., locality by concentric rings, fall of 1938*[1]

Section numbers	Borers observed	Borers parasitized by—				Total	
		Horogenes punctorius		*Lydella stabulans grisescens*			
	Number	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
1	89	10	11.2	0	0	10	11.2
2–7	473	69	14.6	4	0.8	73	15.4
8–19	939	99	10.5	15	1.6	114	12.1
20–28	790	61	7.7	4	.5	65	8.2
29–40	1,175	47	4.0	14	1.2	61	5.2
1–7	562	79	14.1	4	.7	83	14.8
1–19	1,501	178	11.8	19	1.3	197	13.1
1–28	2,291	239	10.4	23	1.0	262	11.4
1–40	3,466	286	8.3	37	1.1	323	9.4

[1] Area surveyed: Center circle, 1 mile in diameter (sec. 1), surrounded by four rings (secs. 2–7, 8–19, 20–28, and 29–40, respectively), each 1 mile wide.

TABLE 39.—*European corn borer parasitization for a comparable district (a circular area of over 7 square miles around the point of parasite release) at East Hartford, Conn., 1934–40*

Year	Borers parasitized by—		Total
	Horogenes punctorius	*Lydella stabulans grisescens*	
	Percent	*Percent*	*Percent*
1934	0.27	1.33	1.60
1935	3.62	2.21	5.83
1936	3.40	.69	4.09
1937	7.94	.53	8.47
1938	14.06	.71	14.77
1939	14.10	1.50	15.60
1940	20.00	5.00	25.00

East Hartford locality over the 5-year period 1934–38. Parasites were originally released in 1934. The parasitization of the borer in this central district in the fall of 1938 is shown to be 14.8 percent, which approximates the 5-year equilibrium position of parasites at Malden, Mass. As previously indicated, it is probable that the equilibrium position of parasites, as determined by the percentage of borers parasitized at East Hartford, will be considerably higher than that at Malden, Mass.

MISCELLANEOUS POINTS IN THE EASTERN STATES

At other points surveyed recently in the multiple-generation area, parasite releases have been of such recent date that con-

clusion relative to their ultimate performance would be premature. The present status of parasites at points surveyed in New Jersey and Virginia has been discussed under the various parasite headings. A considerable number of the points at which releases have been made in the multiple-generation area have not been examined. Probably a number of the parasites that are on a maintenance basis at the surveyed test points have become established at many of the dispersion colony sites.

The Lake States Area

This area is treated as a whole, because only three parasites are known to be established on a maintenance basis in areas where one generation of the borer predominates. In a locality near the southwestern shore of Lake Erie, and definitely limited in its range to the marshland of this locality, the larvaevorid *Lydella stabulans grisescens* is present in considerable concentration. Individual collections near marshland in Lucas County, Ohio, showed a higher percentage of parasitization by *L. stabulans grisescens* alone than that produced by the entire complex of parasites in collections from any other point.

Parasitization within 3½ miles of the Jerusalem Township release point reached 20.9 percent in 1938. Since this was an increase over previous years, it is evident that equilibrium with the host was not reached prior to that year.

The other two parasites, *Eulophus viridulus* and *Chelonus annulipes,* are of more recent establishment and are not coexistent with *Lydella stabulans grisescens* or with each other, and therefore cannot be said to compose an exotic-parasite complex. Their present status has been fully discussed under the respective specific headings.

Although parasites have been released at colony sites other than those at which surveys have been made, it seems probable, from our knowledge of the reaction of the different species at observed test points, that no notable parasitization exists in the Lake States area other than in the limited sections, previously described.

Utilization of Native Hosts by Imported Parasites

In order to determine the extent to which native insects were being utilized as hosts by imported parasites, collections were made in the vicinity of certain release points. All these studies were made incidental to other parasite activities, and in the multiple-generation area they were extremely limited in extent. In the Lake States area, over the 4-year period 1930–33, 46 species of hosts, more or less closely associated with the corn borer, were observed for parasitization. From these, 147 species of parasites, 18 of which were new to science, were reared.

Macrocentrus gifuensis was recovered from *Pyrausta ainsliei* and *P. penitalis* in 1932. This appeared to be a case of accidental parasitization, as *M. gifuensis* failed to recur in collections of subsequent generations of similar hosts.

Eulophus viridulus was recovered from *Pyrausta ainsliei* and *P. penitalis,* and with this species such choice of hosts appears to be a normal occurrence.

FIELD STATUS OF NATIVE PARASITES

From the time when observations were first made to determine the status of European corn borer parasitization in the United States, it was noted that certain of the parasites indigenous to the localities under observation attacked the borer. Surveys conducted over a considerable number of years have indicated that such parasitization has remained at a low level. There has evidently been no tendency toward an increase in attack by native parasites, and where exotic species have become appreciably concentrated, there have been fewer recoveries, both quantitatively and qualitatively, of autochthonous forms.

TRICHOGRAMMA MINUTUM Riley

Native parasites have attacked the borer in all immature stages but the highest concentrations have been recorded on the egg by the cosmopolitan chalcidoid *Trichogramma minutum.* This high parasitization occurs too late in the season, however, to be effective. In the Lake States area corn borer eggs are seldom attacked, but parasitization has been recorded from a few localities in Erie and Lucas Counties, Ohio. In the eastern area parasitization of first-generation eggs is negligible. By the middle of August a small number of second-generation eggs are found to be attacked, and parasitization slowly increases but remains low until the first of September. During the later part of the host-oviposition period, when only a small proportion of the season's total eggs are in the field, parasitization by *T. minutum* rises rapidly. At this time it is not unusual to find over 90 percent of the eggs in the field parasitized by this chalcidoid.

It was early recognized that if this high degree of parasitization could be attained during the maximum oviposition period of the European corn borer, appreciable control would result. Accordingly in 1928, 1929, and 1930 in Massachusetts, and in 1928 and 1929 in Ohio, attempts were made to determine the feasibility of producing such high parasitization artificially by the use of a temporary host.

REARING METHODS

Propagation of host material from which the parasites for the 1928 tests were to be obtained was started in the fall of 1927. The host selected, *Sitotroga cerealella* (Oliv.), was reared the first year in a single large cage holding a ton of wheat spread out in thin layers on 1-inch-mesh wire screening. With the aid of vacuum, moths were collected daily into the oviposition cans, the operator working within the cage. In 1929 and 1930 the rearing cages were reduced to smaller units and the wheat was spread out in shallow trays. The cage as finally adopted embodied many of

the principles later utilized by other workers. By means of a suction tube designed for the purpose, moths for oviposition purposes could be removed from any desired number of cages, or simultaneously from an entire battery (fig. 40).

PARASITIZATION OF HOST EGGS

Host eggs glued to circular cards were parasitized at the rate of about 4,000 parasites per card for distribution in the field.

FIELD TESTS

In 1928 two cornfields in Massachusetts, one at Medford and the other at Saugus, were selected for tests on first-generation eggs of the corn borer. Although these fields had been chosen because of their location in areas of previous heavy infestation, the egg deposition that year in fields under observation was so light as to make parasite-dispersion records unsatisfactory.

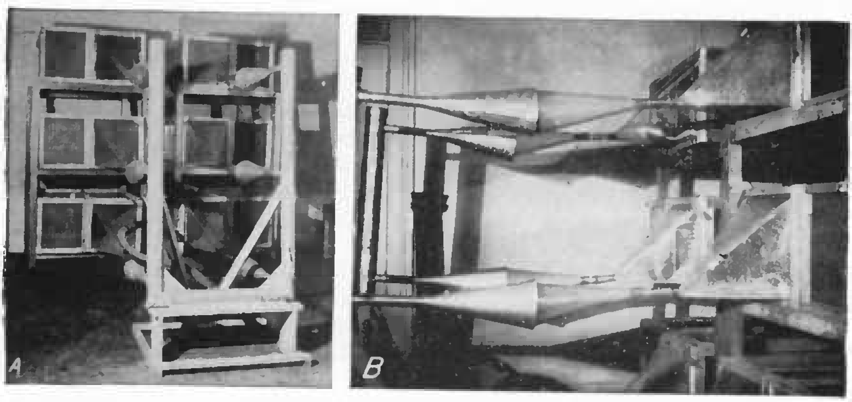

FIGURE 40.—Rearing *Sitotroga cerealella* in the laboratory. Suction apparatus for collecting moths from a large number of cages simultaneously: *A*, General view of unit; *B*, close-up of assembly of unit.

For tests on the second-generation eggs of the 1928 season two fields in Waltham, Mass., were selected. In Field A (0.33 acre) the cards of parasitized eggs were all placed at one point in the center of the field. Liberations were made as follows: August 17, 12,000; August 20, 24,000; August 24, 20,000; and August 28, 20,000, or a total of 76,000 parasites.

In Field B (0.54 acre) there were four liberation points, one in each of the four quarters of the field. Equal numbers of parasitized eggs were placed at each point on each liberation date. Liberations were as follows: August 17, 48,000; August 21, 80,000; August 24, 80,000; and August 28, 48,000, or a total of 256,000 parasites.

In these two fields natural host oviposition was high. In Field A, 2,976 egg masses, or 79,337 eggs, were observed; in Field B, 685 masses containing 17,083 eggs, were found. All host eggs were marked and their fate observed. Observations to discover

new eggs and to observe the status of eggs previously discovered were made on August 17, 24, and 31, and on September 8 and 13. The data on host oviposition and parasitization are given in table 40.

Parasitization in Field B progressed in a manner similar to that in Field A. It increased as the season advanced, and paralleled the usual course of *Trichogramma minutum* on the second generation of the corn borer in eastern New England (table 40).

Although parasitization of host eggs laid during the latter part of the oviposition period reached nearly 70 percent, the average parasitization of the eggs of that generation was only 27 percent. A record was kept of the position of all eggs in the field. The percentage of parasitization was highest in the parts of the field that had the highest concentration of host eggs.

The parasitization in Field B was not so high as in Field A, even though parasites were released in Field B at the rate of nearly one-half million per acre.

TABLE 40.—*Oviposition and parasitization by Trichogramma minutum in Field A in tests on the second-generation host eggs, 1928*

Observation date	Fresh eggs observed		Fresh host eggs that became parasitized		Percent of fresh host eggs found at each examination that became parasitized
	Number	Percent	Number	Percent of total parasitized eggs	
Aug. 17	15,797	19.91	642	2.96	4.06
Aug. 24	16,328	20.59	2,508	11.55	15.36
Aug. 31	32,158	40.54	10,334	47.59	32.14
Sept. 8	11,374	14.34	5,714	26.31	50.24
Sept. 13	3,660	4.61	2,517	11.59	68.77
Total	79,317	100.00	21,715	100.00	27.38

Although the numbers of eggs deposited in these fields were high, their distribution in the field was not sufficiently uniform to obtain the most accurate data on the dispersion of the parasite. Accordingly, in 1929 controlled infestation was resorted to and host eggs laid on growing corn leaves were obtained at all desired points in the field. The method employed to obtain this result consisted of placing one male and three female moths in a small wire cage over the corn leaf upon which the eggs were desired. This infestation was accomplished in June at the time when first-generation corn borer eggs were being laid in the field. A total of 97,000 parasites, or about 340,000 per acre, were released on three dates, as follows: June 22, 32,000; June 27, 35,000; and July 2, 30,000.

Although parasitization in the immediate vicinity of the release points reached about 30 percent, the percentage of parasitization decreased rapidly as the distance from the release points increased, and the total parasitization of all the eggs in the field

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averaged only 8 percent. Parasitization of eggs in a check field taken during the last part of the first-generation oviposition period averaged about 2 percent.

In 1930 the *Trichogramma minutum* tests were repeated, using controlled infestations and timing these infestations to correspond with the natural oviposition periods of both the one and two generations of the hosts. Parasites were released in the test fields at the rate of over 400,000 per acre for each generation.

As in 1929, a slight but economically valueless increase in parasitization over that of eggs in check fields was noted in the host eggs of the first generation. No increase over natural parasitization was obtained from parasite releases against second-generation host eggs.

It was thought that releases of parasites in the vicinity of cornfields sufficiently early in the season might permit natural increase of the parasite on native hosts to numbers of beneficial magnitude by the time corn borer host eggs appeared. To test this possibility, over 650,000 parasites were released in the vicinity of a small cornfield in a heavy growth of grass, weeds, berry bushes, deciduous shrubs, and various species of trees. These releases started on May 1 and were completed before June 10. No increase in parasitization on corn borer eggs was noted as a result of these releases.

Tests with *Trichogramma minutum* in 1928 and 1929 in Toledo, Ohio, on eggs of the single-generation strain of the borer produced a low percentage of parasitization as an average for large fields (10 acres). In these fields, as in those observations in Massachusetts, parasitization was highest in the immediate vicinity of the release points.

From all tests it appeared that the maximum spread as a direct result of a liberation was not over 100 feet, and dispersion to a distance greater than 50 feet was unusual. It appears, therefore, that when the liberations are made as outlined above very little benefit can be expected from releases of *Trichogramma minutum* for corn borer control.

Aplomya caesar (Ald.)

Because of the confusion that existed for a number of years regarding the identity of this and the imported species *Aplomya mitis*, all recovered flies that answered their general description were classified as the native species. This is more fully treated under the foregoing discussion of *A. mitis*. *A. caesar* has been recovered in greater numbers than any of the native parasites except *Trichogramma minutum*. In some years, in restricted areas, a considerable number of corn borers are killed by it. In 1936 the parasite was abundant in several collections of corn borer larvae from Lake and Summit Counties, Ohio, and in one collection from Northampton Township, in which over 30 percent of the borers were parasitized by it.

In the Lake States area most of the parasites of this species attacking single-generation borers emerge before winter. The proportion of those doing so, however, varies with their geographical location. In 1938 over 90 percent of the specimens

recovered in Ohio had emerged prior to the time of collection in the fall, whereas only 60 percent of those taken in Michigan had emerged. Also, of those puparia formed by larvae issuing from the hosts prior to the October collections, none had failed to emerge among those collected in Ohio; whereas, of those taken along the Detroit River in Michigan, 30 percent had died, a fact indicating that the advent of cold weather in the autumn constitutes a mortality factor with this species, as with *Lydella stabulans grisescens.*

There is no indication of increase in parasitization by *Aplomya caesar.*

LABRORYCHUS PRISMATICUS (Norton)

This native ichneumonid attacks the European corn borer larva, but emerges from the pupa. It is recovered from single-generation hosts in the Lake States area and from pupae of both generations in New England. Larvae parasitized by *Labrorychus prismaticus* usually pupate a short time in advance of nonparasitized borers.

The percentage of borers attacked is always low, and there has been no indication that it is increasing in importance as a parasite of the corn borer.

BASSUS AGILIS (Cress.)

This ichneumonid has been recovered from borers in both the Lake States and the Eastern area, but is more prevalent in the latter. Parasitization by the species over large areas never averages more than 1 percent, but in some years in restricted localities as high as 10 percent of the borers have been attacked by it. It has been found attacking the borer as far south as New Jersey.

PYRAUSTOMYIA PENITALIS (Coq.)

Pyraustomyia penitalis is a parasite of the corn borer throughout the northern range of the borer in the United States, but seems to be more prevalent in collections from Ohio and Michigan. This parasite apparently does not have more than one generation on the single-generation strain of borer, since no puparia from which the adults have emerged are found during the year of parasitization where the single-generation strain of host predominates. However, this larvaevorid does attack, and produces one generation on the first generation of borers in areas where the host has two generations.

MICROBRACON CAULICOLA Gahan

This gregarious ectophagous braconid attacks the European corn borer in New England and the Lake States, but seldom attacks it when it is feeding on corn. Between 1930 and 1940, from over 200,000 corn borer larvae taken from corn plants in the Lake States area, only one colony of *Microbracon caulicola* was recovered. However, when corn borer larvae are found associated

with smartweed (*Polygonum* spp.) they are commonly parasitized by *M. caulicola*. In cages used to study the life and seasonal history of parasites, some of the corn borer larvae from a heavy artificial infestation of corn migrated to smartweed growing between the cornstalks in the cage. The larvae in the smartweed showed considerable parasitization from *M. caulicola* adults, which entered the cage, probably through the screening, but the parasite was not found attacking many borers in the corn.

MICROBRACON GELECHIAE (Ashm.)

This gregarious endoparasite is another species that attacks the borer more often when the latter is associated with host plants other than corn. It has been found attacking the early instars of second-generation borers in potatoes at New Haven, Conn. All the borers observed that were killed by this parasite were in the second instar. It was not found to be parasitic on first-generation borers in corn or other host plants.

NEMORILLA MACULOSA (Meig.)

This larvaevorid has been recovered from second-generation borers in New England, where it was observed as an occasional parasite of the borer early in the study of its biological control. *Nemorilla maculosa* is indistinguishable morphologically from the species imported in 1932 from the Orient under the name *N. floralis* (Fall.). No change has occurred in the status of parasites conforming to the description of these species to indicate any specific biological difference between them. As high as 11 percent parasitization of borers from individual fields has been recorded.

PSEUDOPERICHAETA ERECTA (Coq.)

Reference has been made to this species previously as being imported from the Orient under the name of *Pseudoperichaeta roseanae,* an imported parasite from Europe. Although it seems probable that the native species may have occasionally attacked the borer during the early years, no recovery of any parasite corresponding to the description of *P. erecta* has been made from the European corn borer in the United States since 1935.

GAMBRUS ULTIMUS (Cress.)

Gambrus ultimus has been taken both as a primary and a secondary parasite associated with the corn borer. It attacks the corn borer larva, but emerges from the pupa. It has been recorded as a parasite of the corn borer only from New England, and chiefly from the first-generation host. It was recovered as a hyperparasite from the cocoons of *Horogenes punctorius* and, since the increase in concentration of the latter parasite in Massachusetts, *G. ultimus* has been taken in greater numbers as a parasite of *H. punctorius* than as a primary parasite of *Pyrausta nubilalis.*

ITOPLECTIS CONQUISITOR (Say)

Itoplectus conquisitor, like *Gambrus ultimus* attacks the borer in the larval stage, but emerges from the pupa. It, too, acts as a secondary, as well as a primary parasite, being hyperparasitic on *Horogenes punctorius.* It is more beneficial than injurious, however, in that the proportion of European corn borers attacked by it is greater than the proportion of *H. punctorius* cocoons attacked. Although parasitization as high as 5 percent in borers from individual fields is not uncommon, the average parasitization over the area in which it occurs is never more than 1 percent. *I. conquisitor* has not been taken in the Lake States area as a parasite of the corn borer.

GAMBRUS BITUMINOSUS (Cush.)

Two specimens of this ichneumonid were reared at New Haven, Conn., in June 1938. The borers from which they were recovered were infesting cocklebur.

MICROGASTER EPAGOGES Gahan

This braconid is parasitic on borers in the Lake States and in New England, but is recovered more often from borers infesting weeds than from those in corn. It attacks and kills the larval hosts in early instars. It has been recorded from borers infesting potatoes at East Hartford, Conn.

LIXOPHAGA VARIABILIS (Coq.)

Several puparia of this larvaevorid were taken in 1938 from plants infested with the European corn borer. Specimens from Hamden, Conn., were taken on September 2 and from Rochester, N. Y., early in August.

MELANICHNEUMON BREVICINCTOR (Say)

This ichneumonid attacks the host larva but emerges from the pupa. It has been recovered from first-generation corn borer pupae in New England, but has not been observed as parasitic on the borer in the Lake States area.

MELANICHNEUMON RUBICUNDUS (Cress.)

Like *Melanichneumon brevicinctor,* this ichneumonid attacks the mature host larva and emerges from the pupa. Although it is found attacking the corn borer more often in New England, a few records show that it has been taken from single-generation borers in Ohio.

Dibrachys cavus (Walk.)

Although *Dibrachys cavus* functions more often as a hyperparasite on the cocoons and puparia of primary parasites of the corn borer, it has been recorded as a primary parasite on corn borer pupae. A large number of parasites usually issue from each host.

Meteorus loxostege Vier.

This braconid hibernates within the mature host larva. It has been reared from European corn borer larvae collected in New England and in Ohio, but is not common as a corn borer parasite.

Pristomerus (Neopristomerus) melleus Cush.

Two individuals of this species were reared from first-generation larvae of the corn borer collected at Malden, Mass., in the summer of 1937.

Miotropis clisiocampae Ashm.

Pupae of the 1937–38 overwintering generation of corn borers collected in July 1938 in old corn stubble in a weedy field in Jerusalem Township, Lucas County, Ohio, provided large numbers of this chalcid parasite. It was estimated that the parasitization of pupae in this field by this species was about 5 percent. From 1 European corn borer pupa a total of 202 parasites were obtained.

Campoletis perdistinctus (Vier.)

Several specimens of this ichneumonid were taken as parasites on first-generation larvae of the corn borer at North Haven and Hamden, Conn., in 1938.

Macrocentrus robustus Mues.

This braconid was first described from specimens reared from larvae of the European corn borer taken on Cape Cod, Mass., in 1930. Since this parasite has been recovered only from Cape Cod and southeastern Massachusetts, the range of the species is indicated to be very restricted or its numbers extremely scarce. Only a single individual issues from a host insect, and the species has been reared only from second-generation borers.

Apanteles pyralidis Mues.

A single colony of this gregarious braconid was reared from a European corn borer larva collected in York Township, Steuben County, Ind., on October 16, 1930.

ENICOSPILUS PURGATUS (Say)

One individual of this species issued from a corn borer pupa collected in Perkins Township, Erie County, Ohio, on June 25, 1927.

MICROBRACON MELLITOR (Say)

Several specimens of this species were collected at Ecorse, Mich., in 1928. The corn borer larvae from which they were reared were in the fourth instar.

SCAMBUS PTEROPHORI (Ashm.)

This ichneumonid has been taken in eastern Massachusetts, where it parasitizes the second generation of the corn borer. It is recovered more often from borers associated with weeds than from those found in corn. It has not been recorded from the Lake States area.

SCAMBUS TECUMSEH Vier.

A single individual of this species was reared from borers collected at Winchester, Mass., in 1920.

SCAMBUS HISPAE (Harris)

A single specimen was reared from a borer collected at Melrose, Mass., in July 1921.

MICROBRACON N. SP.

This species was reared from borers collected in August 1921 at Lynn, Mass.

INSECT PREDATORS

Muir (*23*) points out that the more efficient insect predators control their host at a lower population level than do species having less searching ability. Predators, he said, are a more mobile death-factor than parasites. They attack both parasitized and unparasitized insects, so they do not greatly disturb the balance.

From observations made in 1938 to evaluate the factors affecting the abundance of the corn borer, it was found that predators had caused the destruction of 17.8 percent of the eggs laid on corn in an area near Toledo, Ohio. In 1939 in this area the loss from predators was 11.0 percent. In 1938 and 1939, 31.7 and 11.1 percent, respectively, of the eggs were classified as missing, but some of them may have been entirely consumed by predators. The predator largely responsible for the egg predation in the Toledo area was *Ceratomegilla fuscilabris* (Muls.). This coccinellid appears early in the season and is responsible for 50 percent

or more of the egg mortality. *C. fuscilabris* is also recorded as feeding on corn borer eggs in New Jersey.

Hippodamia convergens Guer. and *H. tridecimpunctata* (L.) attack the eggs in the latter part of the period in which host egg deposition takes place.

Both the larvae and adults of all these coccinellids have been noted as feeding on corn borer eggs. They are also known to attack small corn borer larvae, although the extent of this predation has never been determined.

Red spiders and chrysopid larvae have been noted as attacking corn borer eggs, but their value as a control factor has not been studied.

BIRDS

An account of studies on the value of birds as factors in control of the borer in New England has been published by Barber (*4*).

In the course of numerous collections of European corn borer larvae in various localities, it was observed that birds seemed to be playing an important part in the reduction of hibernating borers.

In order to study this reduction factor more exactly, a sampling method was tested in the spring of 1933. Twenty fields located at random, covering an area of 38 square miles in York Township, Steuben County, Ind., were utilized in this study. The borer population averaged 6 per 100 stalks in this area. A sample consisted of 100 infested plants from each field, 25 infested plants being taken from each of the 4 quarters. The infested stalks were divided into two classes—those showing bird "pecks" and those without such signs. The stalks showing bird pecks were utilized as the basis for determining the percentage of borer destruction by birds. The following data were obtained from the survey: Eighteen of the 20 sampled fields showed bird-pecked stalks ranging from 6 to 62 percent. Two fields showed no sign of bird-pecked plants, and 5 fields showed borer reductions above 50 percent. The average borer reduction for the 20 fields was 30 percent in all stalks under observation.

A supplementary observation was made in Webster Township, Wood County, Ohio, using 28 fields in a 38-square mile area. All fields showed bird-pecked stalks and these ranged from 1 to 50 percent, with a general average of 15 percent for the district. The borer population was 18 per 100 stalks in this area. It was noted that birds more often attacked stalks that showed considerable evidence of borer feeding (indicating an original population of more than one borer) than those not so badly tunneled. Therefore it is probable that the actual number of borers consumed by birds is greater than the averages noted above. The birds seen feeding on the European corn borer were as follows:

- Downy woodpecker (*Dryobates pubescens medianus* (Swainson))
- Robin (*Turdus migratorius migratorius* (L.))
- Crow (*Corvus brachyrhynchos brachyrhynchos* Brehm.)
- Rusty blackbird (*Euphagus carolinus* (Müller))

Red-winged blackbird (*Agelaius phoeniceus phoeniceus* (L.))
Purple grackle (*Quiscalus quiscula quiscula* (L.))
Chickadee (*Penthestes atricapillus atricapillus* (L.))
Ring-necked pheasant (*Phasianus colchicus torquatus* Gmelin)
Starling (*Sturnus vulgaris vulgaris* L.)

It is difficult to evaluate the role that predators play in borer control, particularly the predators that are active at night, such as rodents and predaceous beetles and their larvae, those that attack free-crawling larvae (either migrants or borers seeking entrance to the plant), and those that attack adults.

No predators of any kind have been imported into the United States for testing against the corn borer.

DISEASE

In the field all stages of the European corn borer seem to be unusually free from disease. Contrary to results noted with several other species of insects, this freedom from attack seems to hold, even under crowded conditions.

In handling material for shipments and under laboratory environments, a fungus disease, *Beauveria bassiana* (Bals) Vuill., occasionally causes considerable mortality. The biology of this organism, as related to the European corn borer, has been studied by Lefebvre (*20, 21*) and by Bartlett and Lefebvre (*5*) who, in 1930, 1931, and 1932, attempted the artificial dissemination of the disease in New England, New York, Pennsylvania, Ohio, and Michigan.

Observations in recent years in the vicinity of some of the points where such artificial infestation was attempted have failed to reveal the presence of the disease in the corn borer. So far as is known, no instance has been recorded of a borer being killed by this disease, except under circumstances traceable to artificially imposed conditions.

It seems evident that no lasting effect has resulted from the artificial dissemination of the causative organism of the disease.

Although several other fungi have been determined as associated with the borer in the laboratory, no mortality in the field has been recorded for which such organisms were known to be directly responsible.

SUMMARY

In the course of investigations during the years 1919–40, on the utilization of natural enemies of the European corn borer (*Pyrausta nubilalis* (Hbn.)) as an aid in its control, over 23 million larvae from Europe and 3 million from the Orient were collected and brought to the United States for rearing their natural enemies contained therein. Other parasites were also collected and forwarded to this country in the cocoon or pupal stages. Of 24 species included in these importations, 22 were sufficiently numerous to permit extensive colonization over the borer-infested area in this country. The number of parasites from this source available for colonization exceeded 2½ million. This supply was

augmented by laboratory breeding and by domestic field collections, the field releases from all sources during this period totaling almost 6½ million adults.

The adults were released at selected localities over the entire infested area where the borer was sufficiently abundant to support a parasite population. Field surveys were maintained at these points to determine which species became established, and to obtain needed information on their biology and environmental requirements as an aid in increasing their distribution within previously colonized areas and in colonizing areas newly infested by the natural spread of the borer. The species known to have become permanently established in this country as a result of these introductions are *Lydella stabulans grisescens* R. D., *Horogenes punctorius* (Roman), *Macrocentrus gifuensis* Ashm., *Eulophus viridulus* Thoms., *Chelonus annulipes* Wesm., and *Phaeogenes nigridens* Wesm.

Twenty-nine species of insects indigenous to the area infested by the corn borer in this country have been observed to parasitize the borer. None of them have been sufficiently numerous to have any appreciable effect on borer abundance. An extensive effort was made to supplement the natural occurrence of *Trichogramma minutum* Riley, which occasionally parasitizes a high percentage of the later portion of the second-generation eggs, by rearing a stock supply of parasites in the laboratory and releasing numbers of them when first- and second-generation eggs were present. Neither permanent nor appreciable temporary benefit resulted from these efforts.

Although no extensive investigations have been made of the role and possible utility that predators can be expected to exert in controlling corn borer populations, birds, particularly the downy woodpecker (*Dryobates pubescens medianus* (Swainson)) and the red-winged blackbird (*Agelaius phoeniceus phoeniceus* (L.)), and insect predators, particularly *Ceratomegilla fuscilabris* (Muls.) and *Hippodamia convergens* Guer., have been frequently observed removing large numbers of corn borer larvae and egg masses from specific fields. No predators of any kind have been imported into the United States for testing against the corn borer.

Beauveria bassiana (Bals) Vuill. is the only disease organism that has been observed in the United States to kill the corn borer in the field, and then only under circumstances directly traceable to artificially imposed conditions. Field recoveries of this disease have been made immediately following its dissemination, but evidently no lasting effect has resulted from efforts to establish it as a natural control of the European corn borer.

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